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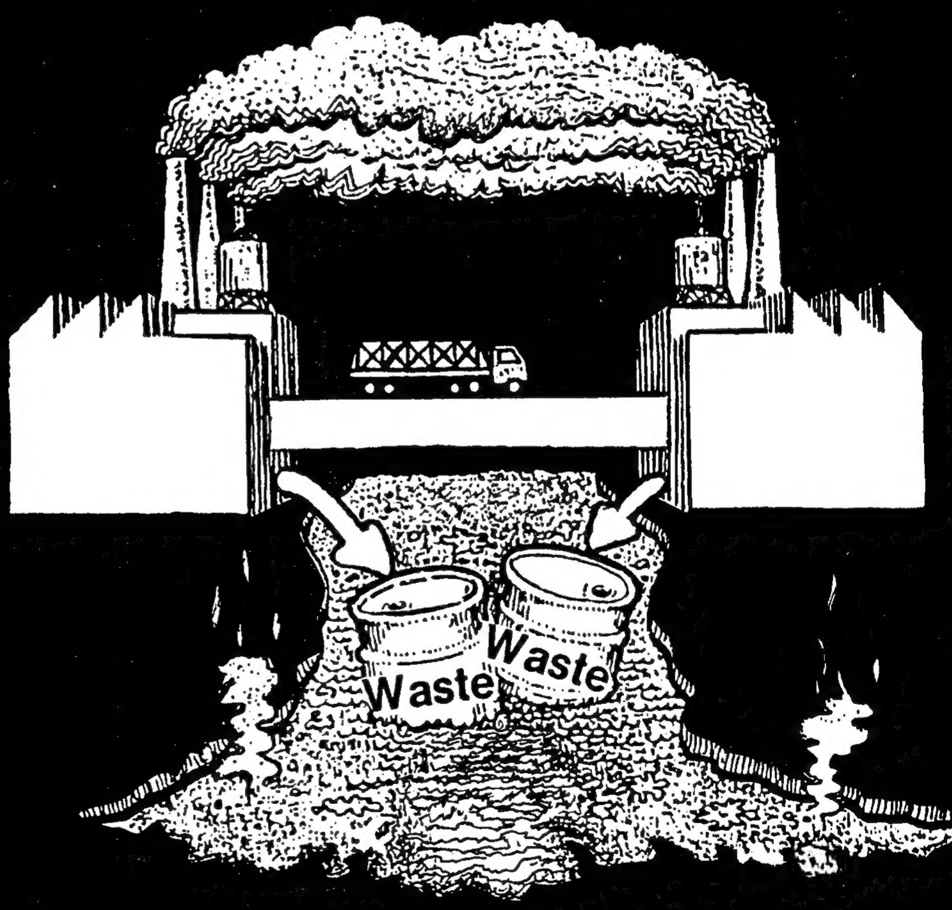

CAUTION — HAZARDOUS MATERIALS
Everyone's Problem

AFRP 400-1

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ARTICLES

DEPARTMENTS

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Hazardous Waste Law: A Survival Guide for Aircraft Maintenance Organizations

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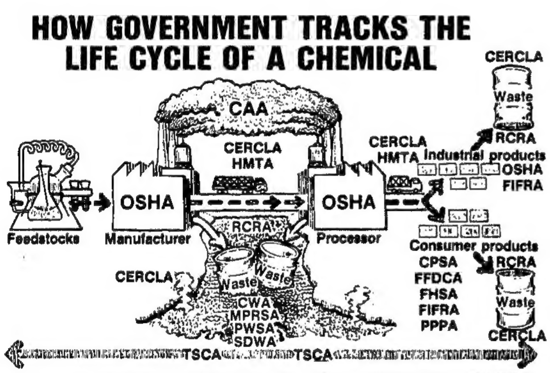
Introduction

Increasing amounts of government legislation and regulation are devoted to the safe management of toxic and hazardous chemicals and materials. Figure 1 gives an idea of the present complexity of this body of law. All these regulations apply to all federal agencies including the Department of Defense. Their effects are increasingly being experienced in flying units where maintenance organizations use many regulated chemicals. This article is for the aircraft maintenance officer starting a maintenance deputate level program as well as other logisticians coping with the existing requirements. It summarizes some of the numerous requirements levied by federal law which increasingly also involve state, county, city, and special regional agencies. Exact requirements vary from state to state.



CAA = Clean Air Act
CPSA = Consumer Product Safety Act
CWA = Clean Water Act
FFDCA = Fed. Food Drug & Cosmetic Act
FHSA = Fed. Hazardous Substances Act
FIFRA = Fed. Insecticide Fungicide & Rodenticide Act
CERCLA = Comprehensive Environmental Response Act Compensation & Liability Act
HMTA = Hazardous Materials Transportation Act
MPRSA = Marine Protection Research & Sanctuaries Act
OSHA = Occupational Safety & Health Act
PPPA = Poison Prevention Packaging Act
PWSA = Ports & Waterways Safety Act
RCRA = Resource Conservation & Recovery Act
SDWA = Safe Drinking Water Act
TSCA = Toxics Substances Control Act

Source: EPA

Figure 1: Laws and Regulations Governing Waste Chemicals.

Regulated Chemicals

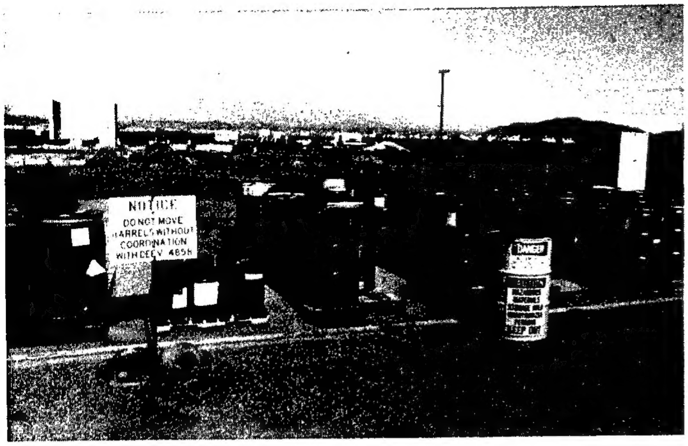
The reason maintenance must be concerned with these laws is its use of a variety of chemicals which are potentially hazardous to personnel or the environment. Many of these chemicals are not consumed in use and, consequently, chemical residue must be disposed of by prescribed procedures. The base bioenvironmental engineer maintains listings of all hazardous materials used on base and their method of disposal. The primary categories of maintenance chemicals and wastes are listed in Figure 2. Use of these chemicals requires the maintenance officer to take certain steps mandated by the various regulations, including planning activities with environmental consequences in mind, training personnel, and establishing proper day-to-day operating and emergency response procedures.

Aircraft Fuels (JP-4, JP-7, AVGAS):
(1) Present in the largest quantity.
(2) Consumed in use or recycled.
Hydrocarbon Solvents:
(1) Used for a variety of cleaning uses and component overhaul processes.
(2) Used in many painting applications.
(3) Largest volume of maintenance generated hazardous wastes.
Acids:
(1) Component of batteries in aircraft, ground equipment, and vehicles.
(2) Used as metal cleaners, particularly in welding operations.
Alkalines:
(1) Specialized aircraft batteries.
(2) Some paint strippers.
Aircraft Hydraulic Fluid:
(1) Periodically requires changing.
(2) Non-recyclable.
Jet Engine Oil:
(1) Periodically requires changing.
(2) Non-recyclable.
Nondestructive Inspection Lab Chemicals:
(1) Variety of specialized dyes and cleaners.
(2) Some consumed in use.
Paint Dregs: Kept separate from other solvent wastes.
Used Rags and Absorbents: When contaminated with the above chemicals.
Empty Drums with Chemical Residue.

Figure 2: Primary Categories of Maintenance Chemicals and Wastes.

Planning

Parts 1500 through 1508 of the *Code of Federal Regulations*, Vol 40, require federal agencies to analyze the potential environmental impact of proposed activities and mission changes. This requirement has not received much attention from the base-level maintenance community. Environmental impact has primarily been left to the Base Civil Engineers (BCE) and their staffs to consider during the project design process. This procedure has worked well for construction projects. However, a variety of maintenance activities also have potential environmental impact. These activities should be listed in each base's maintenance



operating instructions (MOIs). Each MOI is reviewed annually by the maintenance squadrons and staff, generally using an AF Form 673, Request to Issue Publication. Block 8.1 asks if the procedure or activity "involves environmental consequences" and, if the answer is "yes," refers the reviewer to Air Force Regulation (AFR) 19-2, *Environmental Impact Analysis Process*. To avoid potential regulatory violation or criticism, the quality assurance (QA) inspector who gives each MOI its final review should also check for possible environmental impact. In questionable cases the inspector should initiate an AF Form 813, Request for Environmental Impact Analysis, and send it to the BCE for evaluation. As detailed in AFR 19-2, Attachment 7, many MOIs implement requirements from higher headquarters publications and may qualify for categorical exemption from further analysis. This determination is made by the BCE. If necessary, the BCE can call upon the base bioenvironmental engineer and the base Judge Advocate General (JAG) for advice. BCE must conduct any further analysis that is required and must submit that analysis to the base Environmental Protection Committee (EPC) for approval. The role of the EPC is detailed in AFR 19-1, *Pollution Abatement and Environmental Quality*. Because the courts have consistently held that environmental consequences must be a part of all decision making where hazardous chemicals are involved, it is essential that maintenance planners coordinate with BCE when planning a maintenance activity change. Despite the additional paperwork, this coordination could prevent a violation and potential lawsuit by environmental interests or local governments. Other resources base personnel can use when planning or evaluating environmental projects or problems are the MAJCOM environmental engineer and the Air Force Regional Civil Engineer (AFRCE). AFRCE offices located in Atlanta, Dallas, and San Francisco have environmental engineering specialists who can provide expert assistance.

Personnel Training

A significant amount of training is required in order to comply with federal and USAF regulations. Hazardous materials training should cover:

(1) Definition of hazardous waste and hazardous materials.

(2) Types of hazardous materials used in maintenance; safe handling procedures.

(3) Chemicals and safety equipment used on the flight line.

(4) First aid for chemical exposure.

(5) Hazardous waste storage and turn-in procedures.

(6) Emergency spill response.

Presently, each base develops this training locally. One approach to managing this program is to use the standard AFR 50-23, *On-the-Job Training*, process to develop training lesson plans. Annual training can be documented using the existing maintenance management information and control system (MMICS) training program. The MMICS computer can be programmed to require environmental training for anyone who is assigned to preidentified work centers. If MMICS is not used, AF Form 55, Employee Safety and Health Record, should be used and inserted in the individual's AF Form 623, On-the-Job Training Record.

Lesson plans must be developed by the most experienced person(s) available. In most cases the expert in maintenance will be the off-equipment maintenance squadron's environmental protection officer (EPO). The EPO should write the lesson plan and have the BCE review it. The EPO can be designated as instructor trainer and can qualify other squadron instructors. These instructors will then train newly assigned personnel and provide annual refresher training. Pertinent regulations and USAF Technical Orders (TOs) for developing a lesson plan are listed in Figure 3.

40 CFR 260, *Applicable State Regulations*
AFR 19-1, *Pollution Abatement and Environmental Quality*
AFR 19-2, *Environmental Impact Analysis Process*
AFR 19-7, *Environmental Pollution Monitoring*
AFR 19-8, *Environmental Protection Committees and Environmental Reporting*
AFR 19-11, *Hazardous Materials/Waste (in final coordination)*
AFR 19-14, *Management of Recoverable and Waste Liquid Petroleum Products*
AFM 91-11, *Solid Waste Management*
AFR 127-12, *Air Force Occupational Safety, Fire Prevention, and Health (AFOSH) Program*
AFR 177-102, *Commercial Transactions at Base Level*
AFOSH Standard 127-31, *Personal Protective Equipment*
AFOSH Standard 127-43, *Flammable and Combustible Liquids*
AFOSH Standard 161-1, *Respiratory Protection Program*
T.O. 1-1-1, *Cleaning of Aerospace Equipment*
T.O. 42A-1-1, *Safety, Fire Precaution and Health Promotion Aspects of Painting, and Paint Removal*
T.O. 42A2-1-1, *Storage Control of Organic Coatings*
T.O. 42B-1-12, *Markings of Chemical Containers*
T.O. 42C-1-12, *Quality Control of Chemicals*
T.O. 42C-1-14, *Neutralization of Corrosive Chemical Materials*
Local spill response, chemical release, and firefighting OPLANS
Local base regulations on oil-water separators, waste fuel and solvent disposal, fire prevention, and environmental planning
Local base hazardous waste management plan, if existent

Figure 3: Applicable Regulations and Technical Orders.

Day-to-Day Operations

The key to any successful hazardous waste program is consistent enforcement of local control procedures, particularly safety and disposal practices. Aircraft maintenance is performed using detailed step-by-step TOs which explain the exact procedures to be followed. These TOs also have safety WARNINGS and CAUTIONS boldly printed in the text and list required safety equipment. However, most TOs do not explain how to dispose of waste chemicals. Normally, they state: "Dispose of in accordance with directives of the local base civil engineer." This is the area where an explicit MOI must detail how excess chemicals will be handled by maintenance personnel. The best office of primary responsibility for developing such an MOI is generally the off-equipment squadron, since in-shop operations generate

the most waste. Flight-line disposal procedures should be thorough but as simple as possible since flight-line workers are constantly under time pressures. All hazardous waste must be placed in properly labeled containers. These are usually 55-gallon drums. It is important to place only those wastes listed on the label into the drums. Mislabeling wastes is a criminal violation in most states and drives up Air Force disposal costs.

Once 55-gallon drums or other containers are filled with hazardous waste, the base must transfer them to an Environmental Protection Agency (EPA) or state permitted treatment or disposal facility. Few bases will want to obtain a disposal permit due to the complex requirements and restrictions that come with it. Consequently, a sound procedure is to have the EPO take custody of waste containers once they are full. The EPO can then apply any additional markings, labels, and completed paperwork required for turn-in (Figure 4). The DD Form 1348-1, DOD Single Line Item Release/Receipt Document (six copies), can easily be adapted to this use. Identifying chemical codes for all common hazardous materials can be found in AFR 71-4, *Preparation of Hazardous Materials for Military Air Shipment*.

HAZARDOUS WASTE

FEDERAL LAW PROHIBITS IMPROPER DISPOSAL

IF FOUND, CONTACT THE NEAREST POLICE, OR PUBLIC SAFETY AUTHORITY, OR THE U.S. ENVIRONMENTAL PROTECTION AGENCY

PROPER U.S. DOT DESCRIPTION XXXXXX X % XXXX
Y % YYYY
Z % ZZZZ

GENERATOR INFORMATION:
NAME USAF
ADDRESS MARCH AFB 22 CES/DEEV
CITY RIVERSIDE STATE CA ZIP 92518

EPA ID NO. CA4570024527 EPA MANIFEST DOCUMENT NO. EPA WASTE NO. XXXX

ACCUMULATION START DATE XXXXXX STATE MANIFEST DOCUMENT NO.

HANDLE WITH CARE!

CONTAINS HAZARDOUS OR TOXIC WASTES

Figure 4: Typical Hazardous Waste Container Label.

Drums are normally turned in at the base Defense Logistic Agency Defense Reutilization and Marketing Office (DRMO). DRMO in turn contracts with a licensed contractor to transport and dispose of the wastes. Presently DRMO pays the contractor out of a fund provided by the Air Force.

While being held at the base pending pickup, wastes should be stored in a facility that has berms to contain any spills, a roof to protect the containers from the weather, proper ventilation, a fence or means to secure the facility, and proper warning signs visible from all directions. Whether BCE maintains a central facility or each organization maintains its own is the base's option. A central location simplifies emergency spill response but can create other problems. Figure 5 details guidelines for controlling maintenance waste.

When available, recycling is an option which removes wastes from any storage time limits. Equipment is increasingly available commercially which will distill solvents, leaving a much smaller volume of residue for turn-in through DRMO. There are also potential cost savings from the use of recycled solvents. At this time, the author is not aware of any standard USAF equipment for producing recycled solvents. However, under USAF's hazardous waste minimization program, bases are encouraged to pursue the recycling option using commercial equipment. The goal of the minimization program is to achieve a 50% reduction in hazardous waste generation by December 1992. MAJCOMs have been tasked to develop waste stream analyses which when complete will help determine the feasibility and practicality of recycling at each base. Based on these analyses, individual projects will be prioritized against funds which have been appropriated for the minimization program. Units pursuing the recycling option can seek approval from Air Force Logistics Command as detailed in T.O. 1-1-1, *Cleaning of Aerospace Equipment*. Recycling projects can often qualify for funding under Productivity Investment Funds (PIF) and Fast Payback Capital Investment (FASCAP). Before proceeding with a recycling

(1) General practices:

a. Keep all containers closed when not in use.

b. Use funnels and personal protective equipment.

c. Leave a 2" to 3" air gap for expansion in liquid waste containers.

d. Dispose of waste only in a designated container. Do not mix types of wastes. Contact EPO to determine which wastes can be mixed.

(2) Rags and absorbents: Anything used to soak up a hazardous waste must be disposed of as a hazardous waste. Take used rags and absorbents to the designated waste accumulation point. Put into drums marked "USED RAGS."

(3) Oil filters: Dispose of in the same drums as for rags.

(4) Materials which have exceeded shelf-life limits: Turn unopened items back in to the base supply system. Turn opened items in to EPO for disposal.

(5) Damaged containers: If a container is damaged and leaks, the supply system will not accept it back. If possible, transfer it to another container that held the same chemical. Otherwise, package it in a larger container and turn it in through the EPO.

(6) Empty drums: Drums and cans must have no leaks, all bungs and plugs in place, former contents including National Stock Number (NSN) clearly marked, and less than 1" of residue on the bottom.

(7) Full drums: Drums and 5-gallon cans of chemicals ready for turn-in must have no leaks, all bungs and plugs in place, present contents clearly marked including NSN and percentage (example: 90% Skydrol NSN 9150-01-113-2047, 10% water), and a 2" to 3" air gap.

(8) Rinsing containers: Only containers formerly containing aircraft soaps may be washed out and labeled *"triple rinsed."* All other containers must be used as hazardous waste containers for the same type of chemical or turned in to the EPO for proper cleaning.

(9) Transfer of possession to the EPO: Waste containers being filled can be kept at each work center until filled with a 2" to 3" air gap remaining. Once filled, the container must be moved to the base accumulation point within three days. The EPO will inspect each container prior to taking custody and can reject defective or overfilled containers.

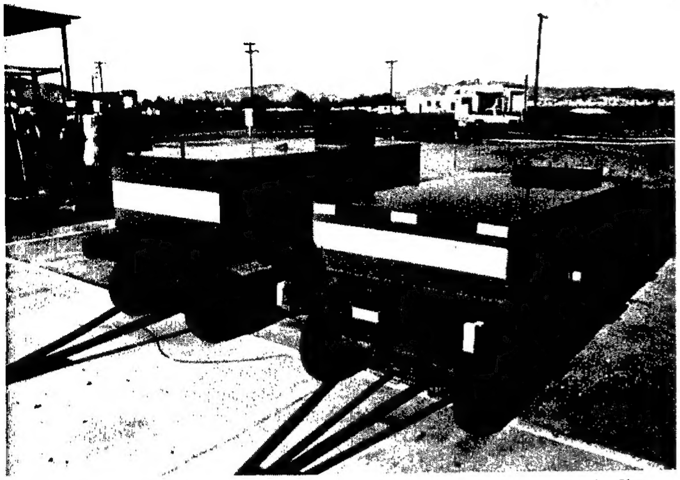
(10) Flight-line chemicals

a. Aircraft fuel: All aircraft fuel will be disposed of in an approved fuel bowser (trailer mounted tank with appropriate safety features). Drain the bowser into the recycling tank maintained by the fuels branch of the base supply squadron.

b. Jet Engine Oil: All jet engine oil will be disposed of in one of the jet engine oil bowsers. Transfer the oil to 55-gallon drums for disposal.

c. Hydraulic fluids: Waste hydraulic fluid types will not be mixed. They will be poured into designated and marked 55-gallon drums.

Figure 5: Sample Hazardous Waste Handling and Turn-in Procedures.

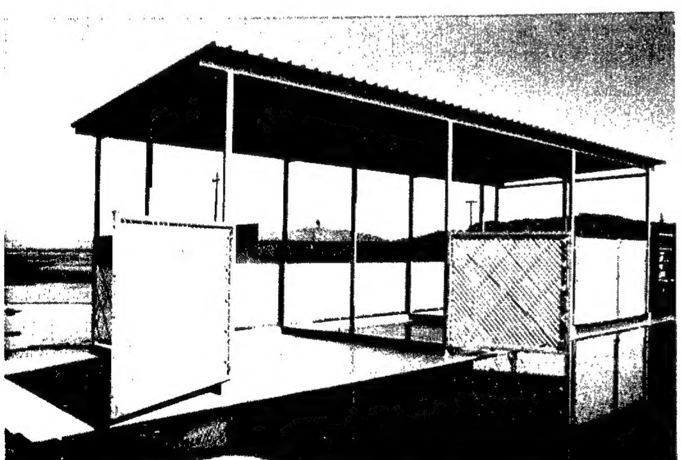


The bowser is an excellent chemical container for flight-line wastes.

program, the base should check to see whether any state hazardous waste permits may be needed.

Emergency Response

The goal of hazardous materials management is to prevent spills and emergency situations. Most flight-line and shop spills are usually easily contained and cleaned up using absorbents. However, if a spill cannot be contained, maintenance personnel must know how to initiate the base response plan. By AFR 355-1, *Planning and Operations,* all bases must prepare a local Operations Plan (OPLAN) to deal with major peacetime disasters. Maintenance is not the only base activity tasked with emergency response. The OPLAN must detail the role of the base command post, fire department, hospital, security police, bioenvironmental engineer, disaster preparedness office, weather forecast detachment, Air Force and EPA reporting requirements, and



A modern waste storage area under construction.

involvement of local government agencies. As in the civilian sector, the base fire department is the lead agency when dealing with unknown and released toxics. Bases periodically conduct exercises where release of green smoke simulates release of toxic chemicals. A base's ability to respond to

disasters is also tested during the periodic Inspector General evaluation.

Conclusion

Compliance with hazardous materials laws is a difficult and complex task. There are a large number of civilian and government agencies involved, each producing regulations which are often imperfectly coordinated with each other. USAF response to these regulations is presently largely left up to the bases because of the local regulatory requirements, although the DOD Installation Restoration Program provides a general framework for identifying and cleaning up existing waste problems. All this unfortunately places the burden of compliance on the middle managers who are the users and generators of chemical wastes. Since much of the necessary expertise lies with the BCE, cooperation and action from bioenvironmental engineers and JAG (a team approach) are critical to a successful program. While even the experts are often uncertain of the exact path to follow, a good faith effort to develop a sound hazardous waste program will determine the base's credibility on an issue which is highly visible and of extreme interest to the communities around our facilities. USAF attention on waste management will continue to increase as regulatory agencies become more aggressive and as all in the command chain realize their liability under toxic and hazardous waste laws.

Conversion from JP-4 to JP-8 Jet Fuel

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This past year marked the 50th anniversary of the first successful test of the gas turbine engine. After trying a number of different fuels, Sir Frank Whittle, a British engineer, fueled his "turbojet" with kerosene on 12 April 1937 and launched a new era in aviation. Kerosene-based turbine engine fuels have continued as a standard for the British Royal Air Force, as well as for commercial jet aviation worldwide, since that date. As a result of wartime collaboration with the British, the US began its work in turbine engine development with a kerosene-based fuel, designated JP-1. However, unlike British refineries, US refineries were engineered to maximize the production of gasoline and, as a result of supply availability problems, the specification for US turbine engine fuel evolved into the development of gasoline-based JP-4 by 1951. JP-4 then remained the primary USAF fuel.

The British, as well as the Germans, were able to test the turbine powered aircraft in the final months of World War II. But, it was not until the Korean conflict that the first US jet aircraft saw combat. Because of the nature of combat operations, JP-4 was not considered a liability in that conflict. In Vietnam, however, where low altitude tactics increased exposure to gunfire, the low flash point and high vaporization rate of JP-4 became a distinct disadvantage. Over half of our aircraft combat losses were attributed to gunfire-induced fuel fires and explosions. This situation was so serious that the Tactical Air Command (TAC) requested a safer fuel be developed to replace JP-4.

The TAC request led to the development of JP-8, which is essentially a kerosene-based commercial jet A-1 turbine fuel with a military additive package. The Air Force Systems Command conducted tests and found that JP-8, which has a minimum flash point of 100°F, as compared to −20° for JP-4, reduces the probability of gunfire-induced ignition by 31%. Unlike JP-8, the high volatility of JP-4 produces flammable vapors at temperatures above −20°. Consequently, with JP-4, large quantities of vapor are available to feed an explosion and fire. The overpressure created upon ignition (the amount of energy created in an explosion) can be up to 260% greater for JP-4; thus, the damage potential is much higher. When ignition occurs, the probability of a sustained fire is 3% for JP-8 as compared to 68% for JP-4. In JP-8 tests, 97% of the fires lasted less than 2 seconds because of the low amount of vapors available to feed the fires. Studies of aircraft crashes also indicate that the probability of a post-crash fire with JP-8 is reduced by 12%. The flame spread rate is a safety related advantage of JP-8 that can be important in dealing with large fuel spills. The flame spread rate of JP-4 is up to 750 times faster than JP-8. Fire can cross a 10-foot pool of JP-4 in 1 second, while it takes up to 12 minutes for a flame to cross the same size pool of JP-8. At most ambient temperatures, a fleet-footed maintenance technician can easily outrun a JP-8 fire. This is particularly important when working in aircraft shelters, such as used in Europe.

Not all aircraft losses are the result of combat or crashes. Fuel fires and explosions caused by stray electrical currents, static electricity, and lightning have accounted for the loss of a number of Air Force aircraft. This past year, we lost a KC-10 and KC-135 in such accidents. In recent years, we lost three B-52s, two C-5s, two KC-135s, an F-4, and a C-130 in similar accidents. Other aircraft have been damaged but not completely destroyed in JP-4 related accidents. Additionally, we have had a number of accidents involving JP-4 storage and handling facilities. The two most serious involved the explosion of a 40,000 barrel tank during April 1986. Over 25 lives were lost in the foregoing accidents, and fire propagation experts claim these accidents would not have occurred had JP-8 been used.

April 1986 was also the month the North Atlantic Treaty Alliance agreed to convert to JP-8 as the standard turbine fuel for ground-based aircraft in Europe. Conversion of the fuel resupply system in Europe began in January 1987 and, with the exception of Turkey, will be completed this year.

JP-8 is currently used in Southwest Asia, and we plan to convert to JP-8 in the Pacific, beginning with the conversion of Korea and Japan. Our goal is to begin this conversion during 1989. While conversion of overseas theaters—where combat is most likely—is our top priority, we are also considering a conversion within the United States. The Defense Logistics Agency (DLA) is currently investigating supply availability, cost, and other logistics considerations related to such a conversion.

Cost is always an important consideration and, unfortunately, we expect JP-8 to cost more than JP-4. Estimates range from one to ten cents more per gallon for JP-8. We think the average increase will be from three to five cents, and perhaps even less once the petroleum industry adjusts to our requirements. However, considering the potential aircraft savings in the initial phase of a war, the price of conversion appears to be a bargain. There are a number of significant cost-reducing benefits afforded by the use of JP-8 that help offset the increase in fuel acquisition cost. Higher density JP-8 provides about 5% more BTUs per gallon, and this translates into an increase in range for most aircraft. The lower vapor pressure of JP-8 significantly reduces evaporation losses in storage, handling, and flight. The losses are estimated to be in excess of 20,000,000 gallons per year, or about eight-tenths of 1% of our annual consumption. As the vapor pressure of JP-8 is near zero at most ambient conditions, these losses would be virtually eliminated. This would dramatically reduce evaporation losses as a source of air pollution and lower the increasing cost of compliance with environmental protection regulations. Additionally, significant savings would be realized as a result of reduced manpower, materials, and

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Supply - RAF Style

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I was quietly enjoying my exchange tour in the Pentagon until your *AFJL* Editor decided that I should earn my keep by writing for the Journal. He thought an article on the RAF Supply system would be appropriate. The subject is too large to cover adequately in one article, so I am guilty of omission and oversimplification. However, I have tried to give you an idea of how the main parts of our system work. The views that follow are entirely mine, but I thank those unknown RAF Suppliers whose briefs and papers I plagiarised for information.

To give you some basis for comparison, I will describe the size of the RAF and how it is organised. I will look at our provisioning and stockholding policies and then outline how our budgetary system works. Next, I will describe our automatic data processing (ADP) systems in some detail. Finally, I will look at our career structures before rounding off by measuring the effectiveness of our supply system.

The RAF

The RAF operates a fleet of about 1,770 aircraft. However, much of our tri-service supply support has been "rationalised." This simply means that the major single service user of a commodity also looks after the needs of the other services. Consequently, the RAF supply system also supports Army and Navy aircraft. In this combined fleet of some 2,800 aircraft, there are about 66 types of aircraft. In supply terms, this translates into a total inventory of over 1.6 million line items. Of these, 1.35 million are held in the RAF and the balance by industry to support their repair lines. In money terms, the value of stock held in the RAF is currently about $6,500M and the annual commitment on requisitions is about $3,500M. In manpower terms, the RAF is 93,000 strong and operates from over 100 bases. I suppose, in quantitative terms, the RAF is roughly one-seventh the size of the USAF.

Organisation

Ministry of Defence (MOD). Our MOD organisation is shown in Figure 1. The Chief of the Air Staff (CAS) answers to both the Chief of the Defence Staff (CDS) and through the Air Force Board to the Defence Council. CDS is our military supremo and the principal adviser to the Secretary of State. In many ways, CDS is our equivalent to your CJCS. The Secretary of State, CDS, and the Service Chiefs are also members of the Defence Council which exercises central policy control over the services. Our Air Force Board, like yours, is responsible for equipping, training, and preparing the Air Force to meet its national and NATO commitments. Our Civil Service is represented at equivalent levels. The

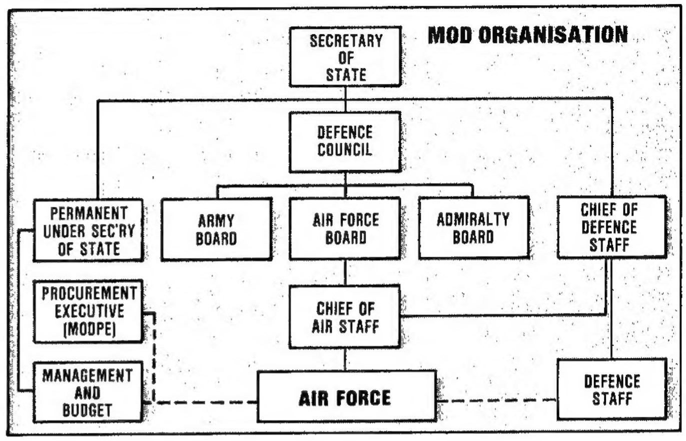

Figure 1.

Procurement Executive (MODPE) buys our equipment. The Office of Management and Budget controls the purse strings. Both answer to the Secretary of State through the Permanent Under-Secretary.

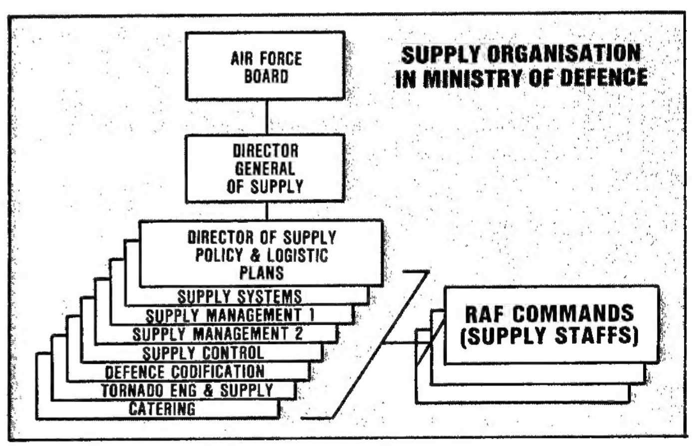

Figure 2.

Supply Organisation in MOD. The head of our Supply Branch is the Director General of Supply (DGS). He is responsible to the Air Force Board for supply and catering support to the RAF. He has eight Directorates supporting him—seven of them dealing with supply activities (Figure 2). The responsibilities of the Directorate of Supply Policy and Logistic Plans are self-evident. Supply Systems looks after supply procedures and regulations. The two Supply Management Directorates provision and manage spares support. Supply Control looks after our supply ADP systems and the Defence Codification Authority maintains the tri-service central database of codification for all items of supply.

Finally, Tornado Engineering and Supply coordinates engineering (maintenance) and supply activity relating to the introduction of the Tornado aircraft. In short, these Directorates are the Supply Staffs at MOD level. They provide policy guidance together with provisioning and system support to the Commands.

RAF Commands. We have three Commands (Figure 3). Strike Command (STC) and RAF Germany (RAFG) control our operational forces. RAF Support Command (RAFSC) provides flying and ground training and logistic support for the RAF.

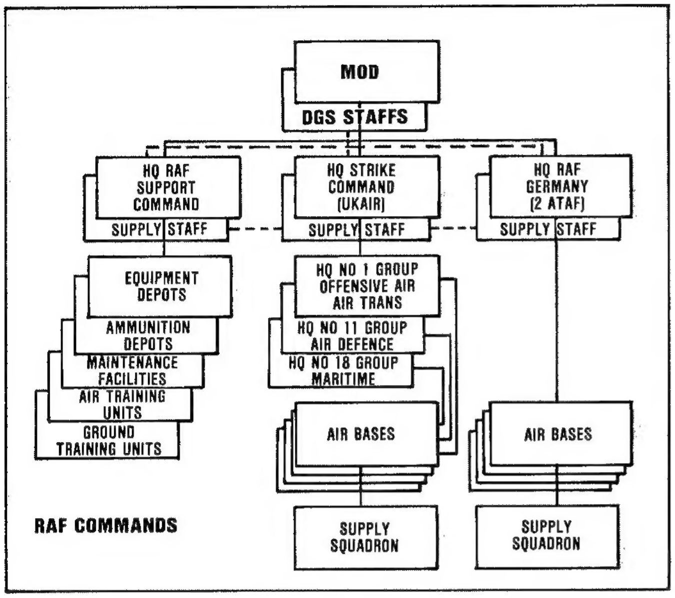

Figure 3.

HQ STC is responsible for our operational bases in the UK it is also HQ UKAIR - the NATO Major Subordinate Command. HQ RAFG is collocated with HQ 2nd Allied Tactical Air Force (2 ATAF) which assumes operational command of RAFG forces in war. Our Supply Staffs at these Headquarters implement MOD supply policies in support of the operational commands and supervise the supply activity at their air bases (RAF Stations).

HQ RAFSC's primary logistic task is to control our Equipment Storage Depots (ESD) and Specialist Repair Units (SRU). We have three ESDs which provide large-scale storage facilities for our technical and barrack stocks. Additionally, we have two specialist ESDs which store explosives, petroleum, oil and lubricants (POL) products, and compressed gases. We also have a number of SRUs throughout the UK and RAFG. They provide in-depth repair facilities for the full range of RAF equipments. RAFSC also operates the ground transportation network which links the RAF stations to ESDs and SRUs. In many ways, RAFSC, with its ESDs and SRUs, performs a similar function to your Air Force Logistics Command (AFLC) and its air logistics centers (ALCs). What is perhaps different is that one of our ESDs parents our Tactical Supply Wing (TSW). This wing provides supply support for our forces that deploy to bare bases in war. Although it has a permanent cadre, TSW manpower is largely drawn from the ESD as required for each contingency. Figure 4 gives you some indication of the nature of their duties.

RAF Stations. The Supply Squadrons on RAF Stations are the front line of our supply system. Typically, a station supports three Flying Squadrons. There would be about 1,500

Figure 4.

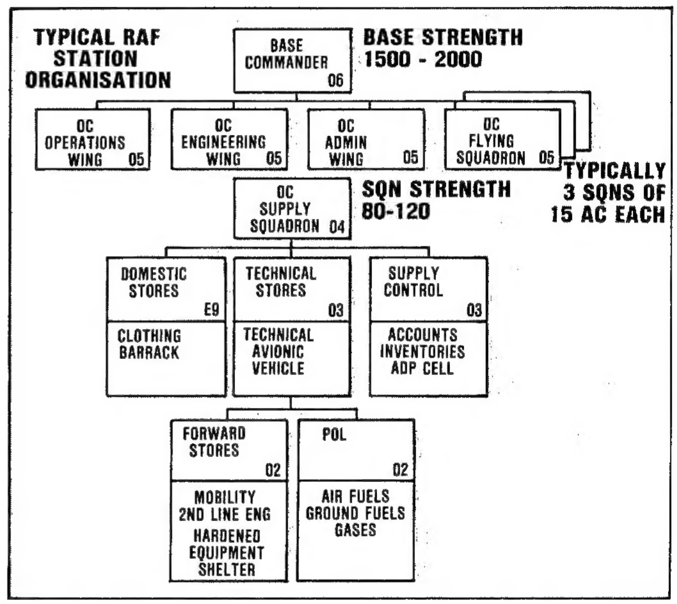

Figure 5.

authorised billets on such a Station, of which some 100 would be suppliers. Our stations are organised as shown in Figure 5. The Supply Squadron comes under either the Administrative or Engineering Wing and it usually consists of three elements. The Supply Control and Accounting Flight maintains the unit supply account. The Domestic Supply Flight sees to the clothing and barrack needs of the station. The Technical Supply Flight (TSF) provides supply support to the station engineers. On the larger stations, the TSF would consist of separate flights providing technical, avionic, and POL support.

Most of our operational stations are semi-hardened. The Flying Squadrons operate from hardened complexes and each is supported by a Hardened Equipment Shelter (HES). The HESs are manned by suppliers and carry a full range of technical spares and mission-essential components such as avionic and hydraulic line replaceable units (LRUs). Each HES is equipped with a computer terminal linked to the central supply system. As far as is practicable, our Supply Squadrons operate in peace as they would in war.

Transportation

Before moving on to look at our provisioning system, I should mention the relationship between Supply and Transportation activities in the RAF. Supply officers supervise both Supply and Air Movements activity. However, the airmen "movers" are in a separate trade group from Supply airmen and are trained specifically on movement duties (primarily air movements). RAF ground transportation is run by our engineers working closely with the suppliers. I know this sounds confusing, but the system works.

Provisioning

Initial Provisioning (IP). The IP process supports new equipment during its introduction. Our requirements calculations are not unlike your own. For each repairable component, we decide what repairs will be done at 1st line (flying squadron), 2nd line (on base), 3rd line (ESD and SRU), and 4th line (industry). We consider such factors as flying hours, predicted reliability, production lead time, and repair turnaround times when calculating the number of repairable components we need to buy. We then analyse the repair process for each repairable to see what piece part spares we need. IP requirements to support the first year or so of service are thus calculated and passed to MODPE for procurement.

Reprovisioning. In-service equipment is supported by the reprovisioning process. All supply transactions are recorded on a central database which provides a real-time record of our global assets and liabilities. An integral part of this system is the automated transaction driven reprovisioning process which records and aggregates usage throughout the RAF. Reorder levels are automatically updated to reflect actual consumption and predicted future trends. Buy reviews are output to Supply Managers automatically. Reorder levels allow for the lead time needed to procure supplies from industry. They also include buffer stocks to absorb surges in demand or interruptions to the replenishment process. The reprovisioning reviews take account of all our existing stock holdings, stock in transit, and dues in from contract. For some low cost spares, the reorder process automatically calculates the buy and places the order on industry without management intervention.

Stockholding Policy

Our stockholding policy is to hold as much of our stocks forward at our Stations as is economic and prudent. Having visibility of our stocks, we can redistribute them between stations and depots as needs arise. Each ESD receives and stores equipment supplied by industry. These stocks are then further distributed to our bases as dictated by the consumption patterns at each base. Generally, some five months worth of stock is held at our ESD and a further three months worth at our bases. Our stocks of repairable items are designed to cover peacetime maintenance requirements. However, we hold additional spares in Fly-Away Packs (similar to your war readiness spares kits) to meet wartime rates of flying for those Squadrons which deploy in war. Munitions and fuel are stockpiled against predetermined NATO requirements and held forward at our bases (where possible).

MOD Budgetary System

Having worked in the Pentagon, I can vouch that our budgetary system is less complicated than yours. The end product of both systems is probably similar, but our pain quotient in getting there is much smaller. Our forecast of financial commitment is carried out in an annual 10-year rolling programme called the Long Term Cost (LTC). The LTC is controlled by the Office of Manpower and Budget and it consists of four stages. First, programme assumptions are established (wish list) and then costed. These assumptions and costs are then scrutinised for realism and consistency (cut). We then develop a coherent and effective programme within the available resources (what we can afford). Our LTC process looks in detail at the first year and constructs a programme to cover the remaining nine years. In this way our short- and long-term aims are constantly being refined and always look ten years out. Our suppliers are involved in each step of the LTC process. We place great emphasis on using our resources more effectively. Our aim is to cut the tail in favour of the teeth. Our success in reducing the logistic burden without degrading readiness and sustainability is largely attributable to the effectiveness of our Supply ADP systems.

RAF Supply ADP Systems

The Central System. We have been extensive users of ADP since our first supply mainframe computer was introduced in 1966. This was a batch-orientated system with a tiny 4K memory. However, it provided us with a central record of all our assets and had a response time of about 10 minutes. It also allowed us to cut 1,260 manpower posts.

In 1974, we replaced this aging system with an on-line, real-time system which linked all our bases throughout the world and gave instant global visibility of our assets. A further 669 manpower posts were cut. These mainframes were replaced in 1984 by our current system based on the Atlas 10 (IBM clone). We have two of these mainframes and each has a 16Mb memory and is rated at 7.5 million instructions per second. Transaction work load has increased to 280K per day but response times are now less than a second.

Our central database is maintained at the RAF Supply Control Centre (RAFSCC) and all our RAF units, both at home and overseas, are linked to this database. Some Army and Navy bases are also connected to our system to support the ranges of equipment we have rationalised between our services. Similarly, the multi-national supply centres supporting Anglo-French projects and the tri-national Tornado aircraft programme are linked to the database.

Distributed Processing. A supply system based on central mainframe computers is vulnerable to damage or sabotage. Our new mainframe, unlike its predecessor, uses hardware that can be replaced at relatively short notice. Therefore, we can now make realistic plans to resurrect the system should the central computer be damaged.

To further enhance system survivability, we have moved to distributed processing at our main operating bases (MOBs). The introduction of the Unit Supply ADP System (USAS) is virtually completed. Our main bases have been equipped with

Honeywell DPS6 computers to maintain their unit records. These are still linked to the central mainframe at the RAFSCC to retain central visibility of our global assets. However, USAS offers our bases a great deal of autonomy. The distributed processors allow them to continue to manage their stocks using ADP even if the central computer goes down.

USAS brought substantial software enhancements. The major feature of this upgrade is the automated control of distributed stocks on our stations. This facility allows us to monitor stock assets and consumption in each of our dispersed HESs and to replenish their stocks automatically. This capability is equally useful at our large repair depots where stocks are also widely dispersed. Planned system enhancements include the total automation of unit priority demand (MICAP) progression. The movement of repairables through the repair cycle will also be captured as an integral part of the supply recording process. Potentially, the introduction of USAS and ATLAS also offered considerable manpower savings, but these were offset by additional manpower needs to operate our dispersed HESs. The net result is that we have improved our war posture without additional manpower costs.

Many of our smaller units will not be equipped with USAS for reasons of cost. These units will continue to operate through directly linked terminals to the central database at the RAFSCC.

Our two largest ESDs are also equipped with distributed processors (ICL 2957) linked to the central database. Internally, depot system users are connected by local area networks (LANs) and the system provides comprehensive local stock management capabilities. Again, to enhance survivability, the depots act as back-up to each other should either computer fail. These large depots also provide database facilities for two other ESDs which are not equipped with their own processors.

ADP in General. We use ADP for other supply control functions. The avionic SRU uses a computer to control the movement of LRUs through the repair facility. A secure system monitors the distribution of aircraft. It also provides statistical data for forecasting aircraft wastage rates (peacetime attrition). ADP systems are used to manage POL, munitions, and aeroengines.

We make extensive use of mathematical models to improve supply performance. For example, our Aeroengine Logistic Simulation model uses Monte Carlo techniques to predict repair and purchase requirements for modular engines. A system has been developed to track items in the repair loop; by modelling this data, we can optimise the number of repairable assets we need to buy. We also use ADP support for our wartime Logistics Command and Control. This simple but effective system provides secure, real-time reporting facilities between all our MOBs and the Command Headquarters. The Air Staff Management Aid (ASMA) is a component of this system and, to let us talk to our colonial cousins, we have even installed ASMA at some USAF bases in Europe.

Supply Career Structure

Our Supply organization employs about 11,500 people. This total comprises 5,000 civilians, 5,500 airmen, and about 950 officers.

Officers enter the branch between the ages of 17½ and 30 and many hold academic degrees. Following Initial Officer Training (bootcamp) at RAF College Cranwell, the survivors attend an 18-week Initial Supply Officers course before taking up their first appointment. During their careers, officers can receive further training on fuels, explosives storage and handling, movements, and ADP. They attend these specialist courses prior to taking up related appointments. Typically, officers will be exposed to virtually every aspect of supply activity during their early years of service.

Promotion is by selection to the rank of Squadron Leader (Major) after about 10 years of productive service (and success in the promotion examination). At this stage, officers are normally appointed to command a Supply Squadron at a Station. Thereafter, they can expect to be allocated to staff duties at MOD and Command Headquarters. Promotion to Wing Commander (Lt Col) is by selection after 4-6 years as a Squadron Leader and to Group Captain (Col) after a further 5-7 years. Thereafter, the going gets really tough. Exit points (with pension) are offered at 38 and 44 years of age. The dedicated can serve until 55 years of age. I won't mention pay as I don't want to blot this article with my teardrops.

The airmen (and airwomen) follow a similar pattern. After 10 weeks' recruit training, they attend a 12-week course on basic supply duties. This course lays a foundation of skills which are progressively enhanced in the early years of service.

One year after training, and subject to passing the Trade Ability Test (TAT), they are promoted to Senior Aircraftmen. Thereafter, promotion is by competition based on annual performance reports. Typically, promotion to Corporal will follow after 3-6 years (subject to passing another TAT and an education test) and to Sergeant after a further 4-5 years. A Trade Management Course at this stage completes their formal professional training. However, like the officers, NCOs attend specialist courses on fuels, explosives, and ADP as necessary. Further, NCOs attend courses which concentrate on developing management and leadership skills; a major element of these courses is devoted to teaching ground defence and basic combat skills. Promotion to Flight Sergeant and then to Warrant Officer is again by selection at about 4-5 year intervals. Airmen initially sign on for a 6-year engagement and this can be extended incrementally to a pensionable engagement of 22 years.

And Finally

To measure the effectiveness of our Supply system, we monitor several indicators. The primary indicator is the demand (requisition) satisfaction rate. On average, some 70% of our units requirements are met from their own shelf stocks. A further 18% are met from depot issues and another 7% from inter-unit transfers. This overall 95% in-system satisfaction rate reflects an average of less than 3% of our aircraft fleet being grounded for lack of spares. We think this performance is good but not good enough. We continue to look for cost-effective ways of enhancing our system. Our goal is to do more with fewer assets: to reduce the logistics burden while enhancing readiness and sustainability.

My years in the RAF Supply Branch have been exciting, demanding, and most enjoyable. As one of the dedicated, I look forward to the fresh challenges awaiting our Branch in the future.

Continuity of Purpose

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In every acquisition life cycle, continuity of purpose is essential to program management. However, continuity of purpose, which provides total understanding of all acquisition life cycle technical activities, is elusive because of the very size of Air Force operations. The effect that size has on continuity of purpose is nowhere more evident than in Air Force attempts to get the system program office to understand the need to buy good product definition data, mainly engineering drawings and associated lists. The following discussion questions the effectiveness of previous Air Force attempts to restore continuity of purpose and suggests a solution: a revised management structure, where Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC) engineering resources are unified under a single Air Force element. The new element would provide continuity of purpose to all phases of the acquisition life cycle—conception, demonstration/validation, full-scale development, production, operation and support, and disposal.

Manageable Corporate Structure

Air Force operations are properly divided into functionally manageable commands to provide each command with the management structure needed to accomplish its primary mission. Generally, the Air Force is divided into users (Military Airlift Command (MAC), Tactical Air Command (TAC), Strategic Air Command (SAC), and Space) and acquirers, suppliers, and supporters (Air Force Communications Command (AFCC), Electronic Security Command (ESC), AFSC, and AFLC). However, for the purpose of this article, only AFSC and AFLC will be considered. These two commands suffer most from the truncation of continuity of purpose during the life cycle acquisition process.

> **"For most system acquisitions, neither AFSC nor AFLC participate in the full acquisition life cycle."**

User commands have continuity of purpose simply because they stay in touch with the total life cycle acquisition process. They identify the threat, generate the statement of operational need, participate in the systems concept definition, support demonstration/validation, advise during full-scale development, conduct testing, prepare facilities for the delivery of production hardware, operate and maintain the hardware, and finally arrange for disposal of deactivated hardware. For most system acquisitions, neither AFSC nor AFLC participate in the full acquisition life cycle. Each has its role and each manages its responsibilities in semi-isolation from the other command. Granted, their tasks are different, their accomplishments are different, and their perspective of the other command's capabilities and responsibilities is different. Reuniting these two giants under one command to gain continuity of purpose is tempting and a recurring proposal, but logic dictates the Air Force maintain separation to have manageable corporate structures. So, how can their differences be constructively channeled into a single continuity of purpose? I propose the engineering discipline as the cohesive element where continuity of purpose may reside. Engineering is common to both commands. It is the discipline to which other elements in all commands turn for guidance and support. Consolidating engineering into a single element, under one leader, would provide continuity of purpose spanning both commands. That continuity is now broken at program management responsibility transfer (PMRT) when engineering responsibility moves from AFSC to AFLC.

Dichotomy of Purpose

In 1949, the Ridenour Committee(1) suggested splitting the Air Materiel Command (AMC) into two commands. Dr Theodore Von Karman, then Chief of the Scientific Advisory Board, supported the split. Initial separation took place in 1951 when the Air Research and Development Command (ARDC) was formed; about ten years later acquisition functions were moved from AMC to ARDC.

The committee recommended a management structure consisting of three functionally distinct commands: Operational, which itself is divided by task into separate commands; Research and Development (R&D); and Logistics. To avoid the duplication of functions prevalent in the Air Materiel Command, they separated the commands by the job each would perform. Evidence of job separation can be seen throughout their report. For instance, they discuss job separation in the following excerpt:

> Development resulting from service use almost always occurs. When a new device is put into the hands of those who must use it in operation, unexpected weaknesses and deficiencies are likely to be uncovered. Such deficiencies will lead to design changes which must, in general, be made either by those responsible for the engineering design, or else by others who work in close cooperation with them. (1:11-3, para B)

This excerpt comes from a section of the report that defines the R&D function, hence the phrase, "who work in close cooperation with them," must refer to a group of engineers, possibly troubleshooters, from the R&D command.

On the other hand, the committee kept R&D out of the production business. They make this point:

The responsibility of the Research and Development command would usually extend through the construction and testing of experimental weapons. The Logistics command would take on the production responsibilities as soon as a decision has been reached to procure equipment for use by the Operational commands. (1:V-6: Para E).

This passage indicates the committee wanted the logistics command to come in early in the acquisition process to actually buy the weapon system—a built-in transfer of management responsibility.

"The separation of responsibility has achieved excellent results, but some knotty problems continue to recur with each PMRT."

Add Resources and Write Rules

Overall, the separation of responsibility has achieved excellent results, but some knotty problems continue to recur with each PMRT. Attempts to solve these problems have been strongly influenced by the prevailing management structures. Objective self-analysis by these structures is impaired by each structure's ingrained way of doing business. So, corrective attempts can have only two solutions—add more resources and/or write more rules. In the early eighties, the lack of adequate drawings to compete spare parts buys was brought to light by the Air Force when it exposed J-57 engine spare parts overpricings—a situation worsened by the use of letter contracts. The press jumped at the Air Force exposé. A media blitz followed from which adverse publicity continues to the present. It now includes the infamous C-5 coffee brewer, F-16 pulley puller, and the Navy's toilet seat. In May 1983, Headquarters United States Air Force (HQ USAF) directed the formation of an Air Force Management Analysis Group (AFMAG) to investigate spares overpricing and to come up with corrective actions. On 29 July 1983, based on preliminary AFMAG findings, the Competition Advocate's role was expanded to include the review of data packages to assure maximum competition when acquiring spare parts. In October 1985, the final AFMAG report was published. It contained 158 recommendations, which primarily added more rules of operation to the acquisition process. One-third of these relate directly to acquiring adequate engineering drawings.

Prior to the release of the AFMAG Report, Congress joined the fray and set its committee staffs to write new laws based on recommendations in the draft AFMAG report—Section 2701, Competition in Contracting Act, and Section 1201, Defense Procurement Reform Act of 1984, to mention just two. These new laws helped solidify the need for the manpower that was added to the Competition Advocate's staff.

This was not the only attempt to resolve the issue of inadequate attention to logistics needs. On 22 January 1982, HQ USAF asked AFSC to establish a Deputy Chief of Staff for Acquisition Logistics to implement an acquisition process to field supportable systems. By April 1983, Acquisition Logistics (now Product Assurance and Acquisition Logistics) offices were established at AFSC Headquarters and at the five product divisions. A memorandum of agreement was later worked out between AFSC and AFLC to develop joint policy, maintain MAJCOM staff surveillance, and provide a management structure to resolve support issues.

So far this move to get logistics up front has generated four new acquisition series regulations and expanded seven existing regulations. It also reportedly added about 75 manpower slots in AFSC. These new and expanded regulations are only the tip of the iceberg. There is probably an equal number of new regulations that impact acquisition in areas other than the acquisition series. New, revised, and existing regulations represent a large amount of reading for the program manager. Just those regulations listed in AFR 800-2, *Acquisition Management,* represent 3,277 pages of direction. Not included in this figure are other categories of regulatory documents, like the command supplements that must also be read, the Federal Acquisition Regulations that tell what can and cannot go on contract, the program management standards that govern acquisition processes, and the specifications and standards to be tailored individually for application to the Statement of Work. If each category of document had approximately the same number of pages as the regulations listed in AFR 800-2, then there would be about 16,385 pages or 9,831,000 words (600 words per page) to be read. Since reading this material is extremely slow, probably 150 words per minute, it would take a person 65,540 minutes or 1,095 hours to read all these documents. If that person could maintain a pace of four hours per day, then it would take one year to finish the task. However, expecting anyone to do this and to retain all that was read without experiencing hands-on application of the principles and procedures involved is equivalent to training a pilot with one pass through a simulator, then turning him loose with a plane loaded with passengers.

But we do the equivalent of one pass through the simulator with some program managers. Those overworked souls must know and understand all the direction contained in those 16,385 pages to supervise their normally short-handed staff. That depth of knowledge takes years to acquire. It is no wonder these program managers turn to contractors for program planning support. Contractors willingly provided this service for a price; however, the contractors' people are not always current in Air Force regulatory requirements. They are trained in company procedures which concentrate on developing the primary weapon and holding logistics considerations until after a production decision is made. This situation is perpetuated because the system program office lacks the resources (engineers) with background and continuity of purpose to challenge the contractor's judgement in program planning.

"Placing engineering under a single leadership and giving them a lead role in program decisions would provide the unifying corporate structure."

While adding more resources and rules may be giving logistics higher visibility, it does not provide the continuity of purpose necessary for responsive management. Continuity can only be achieved by putting the monkey on the back of the Air Force corporate element that makes binding program decisions. That way, when a program office makes a decision which adversely affects a system's long-term life cycle support, it comes back to haunt that office, not an office in a different command at some point in the future. Placing engineering under a single leadership and giving them a lead

role in program decisions would provide the unifying corporate structure.

Yet another attempt to get logistics considered up front occurred in the early seventies when we established the Air Force Acquisition Logistics Division (now, Air Force Acquisition Logistics Center). The new division's prime function was to smooth the transfer of engineering responsibility from AFSC to AFLC. Several hundred workers were added to do the job. Among other services, they furnish deputy program managers for logistics and maintain a library of lessons learned. In 1965, a similar practice was abandoned by the San Bernardino Air Materiel Area when it realized its lessons learned, which were being compiled for the Ballistic Missile Division, were not being read. Hopefully, engineers with lessons learned on modification programs are not now being trapped in a closed loop within AFLC.

Restoration of Continuity of Purpose

The restoration of continuity of purpose must be a first priority action for the Air Force. To this end, I recommend that all engineering be consolidated into a single cohesive element under either SAF/AQ or AFSC for the total acquisition life cycle and that PMRT (for management purposes only) occur automatically at some prearranged point in the acquisition process, which coincides with Dr. Von Karman's 1949 recommendation for the establishment of the two commands.

"If engineering were under a single element, career paths of engineers could move freely between the commands."

Along with restoring continuity of purpose, benefits in training will accrue. Yearly, AFLC installs approximately 130 modifications costing over $1 million each and about 300 modifications costing less than $1 million each. Each modification is itself a mini-acquisition program. That is, the manager or engineer responsible for the modification considers the same issues considered during a major acquisition. What better place to learn or experience acquisition program management or engineering? If all engineering were under a single cohesive element, then the career paths of engineers could move freely between the commands, allowing future program managers and engineers to learn their craft (apprenticeship) on the less costly modification programs, progress to major modifications or less than major acquisition programs, and eventually be elevated to a major system acquisition. Finally, they could return to supervisory positions in modification or acquisition engineering to serve as mentors to the apprentice managers and engineers.

Other Benefits

Another area of benefit would be in the automation of technical information, where integration of automated shortcuts into established management structures needs careful planning and control. Otherwise, workers who lack understanding of the total automation initiative may automate only the present way of doing business and ignore any time- or work-cutting improvements that could be made in the overall management structure.

A good sum of money is being spent to automate (computerize) Air Force data storage and retrieval systems. Although this is necessary, most of the initial effort will go toward capturing the same old data in a new bag. Unfortunately, this effort will not help AFLC get better engineering drawings and associated lists. There are initiatives in work that promise to correct this problem. One such initiative is the Integrated Design Support (IDS) System, being worked by Rockwell International Corporation under the direction of the Air Force Wright Aeronautical Laboratory. IDS is focusing on the capture, management, and communication of technical data from design through logistics operations.

Its first phase, definition of the "as is" functional architecture, has been completed. The next phase will define the "to be" functional architecture from which a system specification for a totally unified data base will be written. Although there are many details yet to be worked, IDS deserves close attention because the evolving "to be" functional architecture hints that present Air Force management structures may not be adaptable to automated management. A willingness to redefine management structures needs to be nurtured. Placing all engineering under a single cohesive element would provide the environment needed to ease the integration of automated management techniques in a planned and controlled manner.

Conclusion

Under present management structures, our goal has been to get logistics considered up front. Continuity of purpose is the element needed to achieve this goal and once-and-for-all integrate logistics into the total acquisition life cycle. A new management structure, with engineering under a single element, would help provide that continuity of purpose. New emphasis on the automation of technical information also supports a move to a more responsive and cohesive management structure. The time is right to address the question: What management structures need to be created? Strong consideration should be given to permanently establishing a cohesive engineering element and mandating program management responsibility transfer at a prearranged point in the acquisition process.

Reference

1. Research and Development in the United States Air Force, Report of Special Committee of the Scientific Advisory Board to the Chief of Staff, USAF, 21 September 1949.

Recommended Readings:

"We Need a Little 'Dash and Daring,' " U.S. Naval Institute *PROCEEDINGS*, April 1988

"The Communist New People's Army," *Military Review*, February 1988

Civilian Career Management

Skills Codes and Career Management

A statement most frequently made to the Logistics Civilian Career Enhancement Program (LCCEP) administrators by registrants is: "I had no idea how important skills codes are." Often, when this statement is made, it is at a point when an employee has not been considered for a job in which he/she was very interested. Skills codes play a significant part in a civilian's career and understanding them is an important step in career management.

What are skills codes? They are the series of alpha and numeric characters found somewhere on an individual's position description. If the position description is typed on the newer forms, the codes are readily apparent in the 34 squares at the bottom of the first page. If the description is on an older form, these codes will be penned somewhere on the first page. Also, experience skills codes are indicated on the automated career brief the servicing personnel office provides individuals for records review.

What do they mean? These codes represent the major duties performed in an employee's job. There are codes for each occupation, and each code represents a specialization within an occupation. Not only are current job skills coded for all civilians, but also their previous experience. The first three characters generally identify the series represented in the job; the second three add specificity to the skill (a shred); and the third three represent a further breakout of the occupation (a subshred). Both current and past experience records can have a maximum of three sets of skills codes. For example: If the skills code shows 50ARN1CEAGK25ARN1CGAGK25ARNPLN, it means that job is a Logistics Management Specialist (ARN) involving 50% of the time in Systems Management (1CE) in Acquisition Logistics (AGK); 25% in Item Management (1CG) in Acquisition Logistics (AGK); and 25% in Planning (PLN).

How are these codes used? These codes and their percentage of application, coupled with pay grades, are used in the automated promotion referral system to identify and compare candidates' knowledges, skills, and abilities with those required in a vacant position. If skills codes are inaccurate or incomplete, that factor can affect a candidate's competitiveness for promotions and reassignments processed through the automated system. For instance, if job analysis has validated that the most highly qualified candidates for a position have had 12 months of experience at the GS-12 level or above in Logistics Systems Management in Acquisition Logistics, the computer searches for GS-12 level or higher experience coded at least 25% for 12 months as ARN1CEAGK. If their experience is coded to "ARN" only, candidates would not be ranked as highly qualified. Thus, any time that skills code shreds and subshreds are applicable, they should be used.

What should civilians do?

(1) Take an active interest in the skills coding of both current and past experience.

(2) Overcome the idea that these hieroglyphics are codes that concern only civilian personnel office staff members.

(3) Review records at the servicing civilian personnel office and find out how experience is skills coded. The personnel office has a table which lists all skills codes and has a listing of skills code definitions which is published by the Air Force Civilian Personnel Management Center.

(4) If you do not agree with the skills coding of a current job, discuss the problem with your supervisor. If the supervisor agrees, contact a servicing classification specialist to resolve the problem. If you do not agree with past experience codes, visit the personnel office, and take all career documentation with you for verification.

Civilians should not overlook the importance of skills codes in managing their careers. It can mean the difference between a *progressive* career or a *stagnant* career. (SOURCE: Glenda E. Atkinson, AFCPMC/DPCMLS, AUTOVON 487-6464)

Most Significant Article Award for 1987

The Editorial Advisory Board has selected "Technology and the American Way of War: Worshiping a False Idol?" by Colonel Dennis M. Drew, USAF, as the most significant article published in the *Air Force Journal of Logistics* during 1987.

Most Significant Article Award

The Editorial Advisory Board has selected "The Evolution of an Air Force Logistics Concept of Operations" by Colonel Richard F. Trainor, CPL, USAF, as the most significant article in the Winter issue of the *Air Force Journal of Logistics*.

Measuring, Evaluating, and Controlling Production and Inventory Systems of Government Contractors

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PART II: Analysis and Recommendations

The first part of this two-part article (Winter 1988 issue) concluded with a foreshadowing of a performance measure, work in process (WIP) turnover, which can provide a measure of contractor performance in managing WIP inventories when progress payments are part of the contract. Part two of the article discusses this concept in considerably more detail together with an overview of current procedures used to evaluate the defense contractor's performance, and concludes by providing an approach to managing WIP. Suggestions are given to improve current procedures along with the savings implications if results are consistent with the data found in this study.

How Government Contractors Differ From Private Industry

The Department of Defense Audit Agency has published a series of reports on the auditing of progress payments to defense contractors, and hearings before Congress have been held related to auditing procedures (Meling, 1980; Tucker, 1984; Senate Hearings, 1984), partially discussed in Part I.[1] These reports concluded that current DOD policies concerning progress payments result from the fact that:

(1) The policy reflects higher interest rates and slow economic growth rates no longer prevalent.

(2) The policies tend to encourage contractors to apply for further progress payments, rather than to improve productivity, and thereby "bill" the taxpayer for their deficiencies in productivity as well as for higher interest rates, high inflation, and difficulty in obtaining capital.

(3) It is difficult to determine exactly at what point in time the costs are incurred.

This often results in contractors maintaining high levels of inventory since their overhead costs are covered by progress payments and may result in what one report calls a "welfare" system, where the government is in effect subsidizing the companies. The overall effect of excessive or premature progress payments is to increase the amount of public debt by tying up a portion of the money paid to contractors in inventory. Since this money is borrowed, the interest payment alone may total millions of dollars.

[1]Progress payment rates have been reduced since 1984 from 90% down to 70% of the total cost of performing a contract. (FAR 32.501-1)

Government contractors are narrowly concerned with satisfying a contract's requirements of cost, schedule, and performance. As a result, contractors may accomplish material and production activities prematurely, resulting in excessive government owned WIP. The cost of financing this WIP is borne by the government but does not show up on the Department of Defense's accounts. Incurring these costs prematurely increases the probability of meeting the schedule with the desired performance. Therefore, contractors are implicitly encouraged into this behavior by the contracting process.

Differences in the way WIP inventory is managed may also be noted if contractors use government owned equipment or facilities rather than company owned facilities. For the contractors this means they must proportion the amount of time the facilities are being used on government work and proportion their charges accordingly. Since they must generally charge the same cost per hour to nongovernment work, to be competitive in the marketplace they have the incentive of keeping total production and inventory costs down. No such stimulus exists for contractors working in totally government owned facilities.

This difference was noted between the two contractors in the following examples. Plant A is government owned whereas Plant B is privately owned. Although it is overly simplistic to assume this one difference is the primary trait which contributed to the more effective managing of WIP inventory for Plant B, it is certainly one of the contributing factors.

Two Mini-Case Study Examples

Two typical, but dissimilar, contractor production facilities were studied in an attempt to evaluate the effectiveness of their production and inventory control systems, particularly as they relate to controlling WIP inventory. Each of these plants (Plant A and Plant B) produces approximately 90% of its output for government contracts, and each plant has a large Plant Representative Office (PRO) which is responsible for overall contract administration. Special attention was given to each PRO's Manufacturing Operations Division, since it is responsible for evaluating the contractor's production performance.

Plant A is government owned and contractor operated to produce aircraft and aircraft parts, modify aircraft, and overhaul aircraft. Approximately 100 major contracts are open at any one time. Production consists of a mixture of fabrication and assembly operations where work is typically processed in lots.

Contractor A has an extensive set of computer programs to plan, schedule, and control production. Master schedules are prepared which incorporate all future contract requirements. The master schedule is passed to the Ordering and Scheduling Department and the Material Planning Department for detailed planning. These two departments interact to determine which parts are to be produced and which must be purchased. The Ordering and Scheduling Department uses block scheduling to determine due dates for job start and completion times. The lead times used in setting due dates are at least 30 days for production plus 25 days for transit time. A particular job's completion due date is no later than the date it is needed by its successor operations. The Material Planning and Procurement Control Department uses job start dates as a due date for completion of its purchasing actions. Purchasing lead times are revised periodically and lead times for raw materials have varied several hundred percent over the past few years. Contractor A's work centers have total responsibility for completing jobs within the block of time scheduled for work.

Contractor A's production and inventory control (PIC) system permits managers at all levels to monitor purchasing and shop floor control. Each of the performance measures discussed previously is used to monitor performance. However, managers are concerned almost exclusively with cost, schedule, and performance, and apparently are insensitive to WIP costs.

The PROs have a formal program used to monitor contractor performance, although contractors are not required to participate, but many do participate on a volunteer basis.[2] Contractor A provides all information and assistance required by its PRO. Each PRO is responsible for developing criteria used to evaluate a contractor's performance. In practice, these criteria do not measure whether lead times are excessive or whether WIP levels are too high. This is perfectly understandable since government programs have never formally evaluated these criteria.

Plant B is privately owned and manufactures three product groups: airborne avionics, electronic warfare, and surface radar. Over 3,000 contracts are generally open at any time. The majority of production operations are assembly; fabrication operations are used primarily for structural components. The plant relies heavily on vendors and subcontractors for components. Production is in lots and is monitored closely throughout the process.

Contractor B uses a very sophisticated data system to plan, schedule, and control production. The major components of this system include (1) a master production schedule, (2) bill of materials, (3) shop floor control, (4) inventory control, and (5) purchasing. A Materials Acquisition Center has been established to oversee material requirements planning. Most importantly, the company has an aggressive program underway to reduce lead times and thereby improve productivity.

Contractor B uses all the performance measures discussed earlier to manage production. WIP costs are not specifically measured, but Contractor B's company managers are unanimous in their recognition of cost, schedule, and performance as their major corporate goals.

The PRO at Plant B uses the same formal program used by the Plant A PRO. The results are different, however, since each PRO developed its own criteria which are uniquely related to a specific contractor. The criteria used at Plant B do not presently address WIP, nor are they required to do so.

In summary, both plants studied used the performance measures described previously to manage production. Neither contractor measures WIP costs directly; however, Contractor B's emphasis on productivity has caused a reduction in lead times for production and purchasing and, as a result, WIP costs have gone down. In contrast, Contractor A's lead time includes liberal allowances for production and purchasing. The potential result is excessive WIP. Each contractor's PRO is aggressively implementing the formal program; however, the program does not specifically address WIP. Instead, government and contractor management attention has been narrowly focused on cost, schedule, and performance. These three criteria are explicitly stated in a government contract, while WIP cost is never addressed. It is clear that WIP cost is a part of true acquisition cost and it involves millions of dollars annually. Contractor B's successes as a by-product of other programs suggest that a major emphasis on WIP cost reduction would be rewarded through significant cost reductions.

Controlling WIP Inventory on Government Contracts

All lead times involved in manufacturing, such as procurement, fabrication, and assembly, are variable to some degree. As a result, an optimum approach to scheduling is to use backward scheduling with allowances built in for lead time variance. Figure 1 is a *conceptual model* which suggests how true acquisition cost is related to the probability of meeting a contract's schedule for delivery. True acquisition cost, as used in Figure 1, is the sum of direct and indirect costs and the financial cost of holding WIP. Direct and indirect costs are explicitly managed through the formal accounting system. The financial cost of holding WIP is hidden and does not show up on any books except the US Treasury Department's as a cost to borrow money. The curve indicates the lowest possible true acquisition cost obtainable to produce a desired probability of meeting contract schedules. The curve implies that the marginal reduction in risk per added dollar of WIP declines rapidly as one approaches high probabilities of meeting a contract's schedule.

The conceptual model suggests that one way to manage WIP is to use backward scheduling with a contract's delivery dates as starting points. This method requires accurate estimates of expected lead times and of lead time variance. The start date of any procurement, fabrication, or assembly activity is simply its due date, minus lead time, minus the required number of

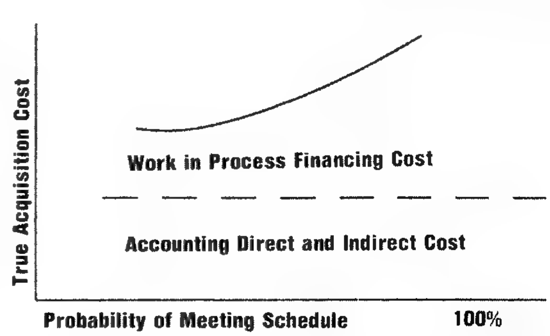

Figure 1: Conceptual Model, Relationship of True Acquisition Cost to Schedule Risk.

[2]USAF PROs monitored contractor performance under the Contractor Management System Evaluation Program (CMSEP), AFCMDR 178-1. This program has been replaced by the Integrated Contractor Assessment Program (ICAP), AFCMDR 178-4.

lead time standard deviations needed to achieve the desired probability of meeting a contractor's delivery schedule. The scheduling process will produce an allowance for queue time based on resource availability.

It should be noted that quality can be viewed in a similar fashion as illustrated in Figure 2. For example, as WIP is driven lower, then the probability of missing a due date increases, which in turn prompts management to take aggressive action to forestall disaster. The individuals actually responsible for an activity (fabrication or assembly) may react to such stress by making more mistakes and reducing product quality.

The concept of WIP as a function of cost, schedule, and performance shows some contractors may schedule activities early to reduce the risk of not meeting a contract's delivery

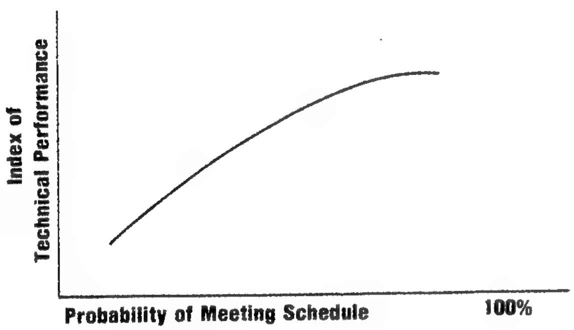

Figure 2: Conceptual Model, Relationship of Technical Performance to Schedule Risk.

schedule and to improve technical performance. The result of such actions is an increase in the financial costs of WIP, and this additional cost is not accounted for by any of the accounting systems used in government contracting.

There are, in general terms, two approaches to the problem of WIP management. One method is to become actively involved in a contractor's production and procurement process to ensure effective procedures are used. Alternatively, one can select a measure or measures of effective WIP management and include this in the contract as an incentive clause. This latter approach would minimize the government's intrusion into a contractor's management system but could motivate it to reduce WIP holding costs. Both approaches are discussed in subsequent sections of this paper.

Proposed ICAP Modifications

Air Force plant representatives manage government contracts under a variety of regulations. Specific policy guidance for manufacturing operations is found in Federal Acquisition Regulations (FAR); Department of Defense FAR Supplements; AFR 800-9, *Manufacturing Management Policy for Air Force Contracts;* and AFSCR 84-2, *Production Readiness Review.* (1-4) The Air Force's Integrated Contractor Assessment Program (ICAP), described in AFCMDR 178-4 (5), *Integrated Contractor Assessment Program,* identified ". . . a standardized set of contractor system elements to AFPRO personnel for their use in continuously evaluating contractor management systems and hardware and software." ICAP's basic intent is to ". . . ensure contractor performance results in acceptable product quality, reasonable cost, and timely delivery." ICAP is not mandatory for contractors; however, contractors do cooperate voluntarily with their resident AFPRO in using the program to monitor contract performance. The manufacturing operations portion of ICAP contains eight Contractor System Elements (CSE) and two of these are relevant to this study. They are "PD-3, MANUFACTURING PLANNING" and "PD-6, PRODUCTION SCHEDULING AND CONTROL." Functional evaluation criteria are used to evaluate each CSE and provisions are made for special factors which may be unique to a single contractor. The following proposed CSE highlights WIP management and could be added to the manufacturing operations portion of ICAP:

> PD-X, WORK IN PROCESS MANAGEMENT. The term "work in process" narrowly defined includes all inventories of materials, work-in-progress, finished goods, and other items of property paid for but not yet delivered to the government. The value of these inventories is measured by the amount of unliquidated progress payments associated with a contract. The government finances these inventories, and it is important to keep the investment in work in process at a minimum level commensurate with meeting a contract's requirements for schedule and performance. Items related to effective work in process management are: (a) accurate procurement and production lead time planning factors, (b) accurate bills of materials, (c) accurate routing documents, (d) accurate inventory records, (e) on-time deliveries by vendors and subcontractors, (f) on-time deliveries by contractors and (g) minimum work in process inventories. A contractor should have realistic goals for each of these factors and demonstrate satisfactory progress toward attaining these goals.

WIP Incentive Clause

The series of monthly holding costs incurred by the government as it finances work in process can be determined after a contract is completed. The future value of this series of costs can also be calculated and implies that a dollar of holding costs incurred in the first month has a greater cost to the government than one incurred in the last month of a contract. The future value of a contract's holding costs will depend upon the particular pattern of deliveries specified in the contract, when progress payments are liquidated, and the timing of incurred costs controlled by a contractor, which create unliquidated progress payments. A target for the future value of WIP holding costs on a new contract can be determined by developing a contractor's WIP profile of unliquidated progress payments on past contracts and by assuming a uniform rate of cost generation up to each specified delivery point. An incentive clause could then be written to permit a contractor to share in the savings if actual WIP holding costs are less than the target or, alternatively, share in the added cost if the goal is exceeded. The clause could also serve as a powerful factor to encourage contractors to develop and use more efficient/effective production and procurement management systems.

Potential Savings

Previously, it was stated that the potential dollar/manpower savings from improved production/inventory control systems were significant. But how significant? Defense Audit Report No. 81-031, dated December 18, 1980, stated: "On December 31, 1979, the 7 AFPROs included in the audit had 159 contracts with unliquidated progress payments amounting to $3.2 billion."

Translating this into interest payments the government incurs by having to borrow money to pay the cost of holding work in process inventory can be done as follows: Treasury bills maturing in six months were yielding approximately 9% on 1 March 1985. Using this rate, the annual holding cost for

the 7 AFPROs is approximately $288 million per year.

Data on average unliquidated progress payments and average annual liquidation of progress payments is difficult to obtain. Data was requested from 21 PROs; however, only 11 were able to respond with useful data. Table 1 summarizes the liquidated and unliquidated progress payment data for the reporting contractors, and gives the WIP turnover ratios.

Table 2 presents the ratio of liquidated to average unliquidated progress payments by year for each contractor. The ratio values range from .07 to 10.01; however, Contractors A and D account for most of this extreme variability. Contractors B and E appear to have stable ratios with means of 1.47 and 1.0 respectively. The data reported by the 11 government contractors covered all activities during a fiscal year. The resultant WIP turnover ratios were volatile in some cases which suggest this measure is very sensitive to the stability of production activity. An alternative measure, however, may be developed which uses the WIP turnover ratio for each contract to determine how efficient a contractor's PIC system is in managing WIP.

Contractor A
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	15.7	5.2	3.02
1981	4.4	11.1	.40
1982	10.6	30.9	.34
1983	84.9	30.7	2.77

Contractor B
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	64.5	39.7	1.62
1981	53.4	35.8	1.49
1982	73.1	44.4	1.65
1983	76.0	67.9	1.12

Contractor C
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	----	----	----
1981	7.8	26.7	.29
1982	45.6	39.6	1.15
1983	33.6	40.0	.83

Contractor D
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	7.6	104.0	.07
1981	224.0	91.9	2.44
1982	529.5	52.9	10.01
1983	573.5	79.1	7.25

Contractor E
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	----	----	----
1981	2.8	2.2	1.27
1982	12.0	12.9	.93
1983	35.5	45.6	.78

Contractor F
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	----	----	----
1981	----	----	----
1982	15.3	54.0	.28
1983	110.7	94.8	1.17

Contractor G
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	448.3	367.5	1.22
1981	480.2	178.0	2.70
1982	206.4	235.0	.88
1983	486.6	476.7	1.02

Contractor H
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	----	109.5	----
1981	134.9	242.4	.56
1982	231.3	299.7	.77
1983	309.6	264.6	1.17

Contractor I
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	25.1	----	----
1981	58.9	37.8	1.56
1982	148.4	97.5	1.52
1983	385.5	216.1	1.78

Contractor J
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	----	----	----
1981	7.8	14.2	.53
1982	45.6	42.4	1.08
1983	33.6	49.6	.68

Contractor K
Progress Payments ($000,000)

Year	Total Liquidated	Average Unliquidated	WIP Turnover Ratio
1980	1858.8	----	----
1981	2994.7	828.5	3.61
1982	3387.4	870.5	3.89
1983	3962.1	931.9	4.25

Table 1.

Summary of Contractor WIP Turnover Ratio

Contractor

Year	A	B	C	D	E	F	G	H	I	J	K
1980	3.02	1.62	----	.07	----	----	1.22	----	----	----	----
1981	.40	1.49	.29	2.44	1.27	----	2.70	.56	1.56	.53	3.61
1982	.34	1.65	1.15	10.01	.93	.28	.88	.77	1.52	1.08	3.89
1983	2.71	1.12	.83	7.25	.78	1.17	1.02	1.17	1.78	.68	4.25

Table 2.

Individual Contract WIP Ratio

The Department of Defense conducted a study of contract pricing, financing, and profit, and published its findings as the *Defense Financial and Investment Review*, June 1985. One of the difficulties faced when trying to estimate the magnitude of this problem was how to reach conclusions about such diverse products manufactured by the defense industry:

> To analyze the working capital requirements of defense contracts, a 'typical' contract was created from the actual performance of selected contracts. Twelve recently completed contracts, representing major

Cash Flow Analysis of "Typical" Contract

Month	Costs Incurred	Process Payment Billed	Delivery Payment Billed	EOM Unbilled Inventory
1	$ 46,648	$ 41,983	$ 0	$ 4,665
2	74,137	66,723	0	12,079
3	83,300	74,970	0	20,409
4	188,552	169,697	0	39,264
5	250,576	225,518	0	64,321
6	271,250	244,125	0	91,446
7	271,250	244,125	0	118,571
8	271,250	244,125	0	145,696
9	271,250	244,125	0	172,821
10	271,250	244,125	0	199,946
11	271,250	244,125	0	227,071
12	293,583	264,225	0	256,430
13	306,743	276,069	0	287,104
14	311,130	280,017	0	318,217
15	311,130	280,017	0	349,330
16	311,130	280,017	0	380,443
17	311,130	280,017	0	411,556
18	311,130	280,017	0	442,669
19	311,130	280,017	0	473,782
20	311,130	280,017	0	504,895
21	308,632	277,769	0	535,758
22	307,161	276,445	0	566,474
23	306,670	276,003	0	597,141
24	306,670	276,003	0	627,808
25	306,670	276,003	0	658,475
26	306,670	276,003	0	689,142
27	306,670	276,003	0	719,809
28	306,670	276,003	0	750,476
29	306,670	276,003	0	781,143
30	258,835	232,951	0	807,027
31	230,646	207,581	0	830,091
32	221,250	199,125	0	852,216
33	221,250	199,125	0	874,341
34	221,250	199,125	250,000	646,466
35	221,250	199,125	0	668,591
36	221,250	199,125	250,000	440,716
37	221,250	199,125	0	462,841
38	143,998	129,598	250,000	227,241
39	98,474	88,627	0	237,089
40	129,115	0	366,203	0
TOTAL	$10,000,000	$8,883,796	$1,116,203	

Table 3.

end-items (aircraft, missiles, vehicles, electronic) were used to build a composite cost and delivery profile. (Page IV-II)

The "typical" contract's cash flow was summarized in Exhibit 8, page IV-16, partially reproduced here as Table 3, and included a sequence of progress payments, delivery payments, and liquidation through delivery for a $10 million contract. The progress payments are incurred over the contract's life. The contract covered 40 months and, when analyzed, showed average unliquidated progress payments of $3.8 million over the life of the contract. The ratio of contract cost to average unliquidated progress payments was 2.60 implying that this typical contract produced an average of $2.6 worth of product deliveries for every dollar of government-owned and financed WIP represented by average unliquidated progress payments. The typical contract developed by the DOD study team also implies that a $10 million contract generates average unliquidated progress payments of $3.8 million or 38% of a contract's price.

The DOD study (page IV-28) states that, in 1984, approximately $56.7 billion worth of contracts were let which contained progress payment clauses. By extrapolation using the analysis presented, these contracts would produce average unliquidated progress payments of approximately $21.5 billion ($56.7 x .38). This also suggests that the government's cost to finance these unliquidated progress payments of WIP at 9% treasury rates would be roughly $1.935 billion per year ($21.5 x .09). As developed earlier, any action which can be taken to reduce average WIP would directly reduce the government's cost to finance WIP.

The limited data do not permit a precise estimate of savings which could result in improving WIP management. The DOD study's typical contract implied a ratio of annual liquidated to average unliquidated progress payments of 2.6, whereas the seven contractors who provided aggregate annual data had ratios of .07 to 10.01. Contractors B and E appear to be stable with WIP ratios of 1.0 to 1.46. If 1.5 is a representative ratio for all contractors, then if contractors adopted a turnover goal of 2.0 and achieved it, this would yield an estimated government saving of nearly $800 million for the 1984 contract data and assumptions; i.e., reduce holding costs from $3.4 down to $2.6 billion (Table 4). It is quite possible that aggressive contractor efforts could improve this measure of productivity above the 2.0 level. Table 4 gives the government's cost of financing WIP for different turnover measures at an interest rate of 9%.

Projected WIP Holding Costs (1984)
($000,000,000)

Contract Value	Average Unliquidated Progress Payments	Ratio	Holding Cost
$56.7	$56.7	1.0	$5.1
56.7	37.8	1.5	3.4
56.7	28.4	2.0	2.6
56.7	22.7	2.5	2.0

Table 4.

Conclusions

It is apparent that emphasis must be placed upon controlling WIP inventory represented by unliquidated progress payments to contractors working on government contract. It is also apparent that procedures and/or approaches need to be specified and systems must be implemented that would allow such emphasis to be effective.

This two-paper series has attempted to outline briefly the magnitude of the WIP problem and then to present a solution that will provide the tools and approaches which would improve upon current practices. No panacea has been presented. Nevertheless, the costs incurred by not effectively controlling WIP inventory are so huge on government contracts with progress payments, that any attention focused upon this very costly area of doing business will certainly uncover many areas of improvement for almost all government contractors.

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Rx

Dear Editor

I was impressed with the comments of the two Colonels in the "Logistics Enquirer" (Winter 1988 issue). They were more attuned to reality, it seems to me, than were the other respondents. In fact, their comments were somewhat along the lines of "home, mother, and outer space"—the company line, you might say! The two Colonels, though, addressed the idea that we cannot continue to allow maintenance to demand more and more sophisticated and complex GSE. In time of war, that stuff probably won't last and our maintenance people will be in deep trouble. We absolutely must begin working toward aircraft, and other equipment, which require no maintenance rather than that which requires more complex, and more quantity of, support equipment. So long as we tie ourselves to that hard line of mandatory need for support equipment, the closer we come to condemning our forces to defeat! There is much to be said for simplicity tied to reliability!

Professor Jerome G. Peppers, Jr.
Fairborn, Ohio

Dear Editor

I was disappointed that the RELOOK article (Fall 1987 issue) made no mention of dispersal as a key factor in survival. The RAF learned this the hard way in the Battle of Britain when most of the airfields in Southeastern UK were under enemy attack, a situation similar to what we expect during a Soviet attack on NATO. The RAF only belatedly learned to site the Operations building and Communications Center away from the airstrips which constitute an easy-to-identify and hard-to-conceal target. Have we learned this lesson? Nettles' article with its many excellent insights seems to ignore this one.

Professor I. B. Holley, Jr.
Major General, AF Reserve (Ret)

Civil Engineering Doctrine

Aerospace combat power is produced through the synchronized efforts of combat operations and combat support. The Air Force now has doctrine describing the enduring principles of combat support and the combat support process (AFM 1-10, *Combat Support Doctrine*). The next step is to develop doctrine for each functional area within combat support. We are doing that for civil engineering through Project Foundation. We are developing doctrine that states the enduring truths regarding manning, organizing, equipping, training, and employing civil engineers as an integral part of combat support. This document will improve the effectiveness of civil engineering across the spectrum of conflict, from the most likely war (low-intensity conflict), to the most potentially devastating with the Soviet Union. (Maj Hicks, AF/LEEX, AUTOVON 225-7744)

WRSK/BLSS Reductions

The realities of this nation's deficit reduction effort are nowhere more evident than in the area of war readiness spares kit (WRSK)/base-level self-sufficiency (BLSS) spares. These, of course, are the stocks the Air Force uses during the first 30 days to transition to wartime operations. From FY84-87, these sustainability requirements have been essentially fully funded, providing the needed warfighting kits for our new force structure (EF-111, F-15/F-16, C-5B, special operations forces (SOF)) as well as the replacement parts for kit items changed by modifications. This momentum, however, has been dramatically interrupted in FY88/89. Because of congressional cuts to our FY88 program and the Air Force's need to maintain readiness within revised FY89 fiscal guidance, we will be unable to buy any war readiness stocks in either FY88 or FY89. This means our new force structure of F-15s/F-16s and SOF aircraft entering the inventory in FY90-91 will be without wartime kits and that those critical configuration changes resulting from modifications (KC-135 reengining, F-16 operational support update, F-15 multi-stage improvement program) will not be made in the kits. While existing spares inventories produced by recent strong funding years will mitigate the short-term risk, continued deficits will sharply increase the risk of our warfighting capability. (Lt Col McClaugherty/Ms Debbie Alexander, AF/LEXW, AUTOVON 225-2792.)

American Merchant Marine Decline

Sealift is of vital importance to the security of the United States. Unfortunately, the American Merchant Marine is in serious trouble and the future does not appear to be very bright. A recent report from the Commission on Merchant Marine and Defense identified the severity of this problem. Just a few of the Commission's findings are:

- Since 1970, the US flag merchant fleet has declined in numbers of ships by over 50%, and the remainder of the fleet is expected to decline by 50% by the year 2000.
- Since 1982, 76 shipyards have closed.
- For the first time in the history of our country, not a single merchant ship was built in the United States in 1987.
- There are only six US liner carriers left in foreign commerce.
- Future USAF planning needs to consider the impacts of a continued decline in the US Merchant Marine. (Mr Thomas W. Spade, AF/LETTC, AUTOVON 227-4742)

Real Property Division Reorganization

Within the next eight years, the Real Property Division (AF/LEER), Directorate of Engineering and Services, plans to lessen its dependence on the US Army Corps of Engineers, which has acted as our "real estate agent" since 1947 for most real estate actions (leasing, real property disposals, outgranting Air Force space, etc.). This change is being made in order to improve response time to Air Force MAJCOM requests for various real property actions.

AF/LEER has been reorganized into a structure similar to that of the Corps, with the exception of the cartographic function, which will remain with the Corps. Training of Air Force real property personnel at all levels (installation/MAJCOM/Air Staff) is being implemented, and actions to ensure adequate staffing of offices are underway. In addition, Secretary of the Air Force Orders (SAFOs) and Air Force regulations are being rewritten to delegate more authority for decision making and accomplishment of real property actions to the lowest feasible levels. Although USAF is incrementally handling more and more real estate actions, complete independence from the Corps is not anticipated. (Mr Charles G. Skidmore, AF/LEERA, AUTOVON 297-4033)

Continued from page 5

aircraft downtime associated with purging requirements prior to maintenance.

Since kerosene-based JP-8 is an excellent diesel fuel substitute, the JP-8 conversion in Europe sparked a joint Air Force and Army initiative to use JP-8 as a single fuel for the battlefield. The concept involves replacing JP-4 and diesel fuel with JP-8 and gradually phasing out gasoline driven automotive equipment. As the realization of this goal is dependent on the gradual attrition of existing gasoline powered assets, we have established a goal of being able to conduct combat operations on a single fuel by the year 2010. The single fuel initiative will dramatically simplify battlefield fuels logistics and enhance tactical flexibility.

Enhanced combat survivability, improved safety, simplified battlefield logistics, and environmental considerations mandate the conversion from JP-4 to JP-8.

MAGIC - Paperless Contracting for the Real World

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A March 1986 report from Deputy Secretary of Defense William H. Taft IV to Congress signaled a profound change in the Department of Defense (DOD) logistics environment. This report noted the acquisition process requires an extremely paper-intensive data exchange between contractors and the government. The volume of this paper flow is growing rapidly, inflating acquisition and support costs. (6:I-3) Taft proposed a bold solution to the problem: convert from the paper-intensive process to an automated digital information exchange. (9) This policy was referred to as Computer Aided Acquisition and Logistic Support (CALS). A few of the foreseen benefits of the CALS initiative are improved reliability and maintainability, 20% to 30% savings in the acquisition cost of technical data, reduction in contracting administrative lead time, improved information accuracy, reduced use of paper products, and enhanced logistic support planning. (6:ES-8)

The report to Congress noted previous attempts at data automation have created "islands of automation." Though automated, these islands communicate with each other through conventional means. (6:ES-3) One solution to this conundrum is to transfer data electronically between islands of automation. The CALS plan recognizes that cooperation between DOD and industry is essential if the transition from paper-intensive to digital data transfer is to succeed. The CALS program is an evolutionary enterprise primarily aimed at new weapon systems. (6:ES-3) While not a part of CALS, a project at Ogden Air Logistics Center seeks to eliminate paperwork in the procurement process by electronically linking existing "islands of automation." The Ogden program endeavors to augment the Air Force link with industry using electronic data transfer. This prototype has been nicknamed MAGIC, an acronym for Manufacturers And Government Interconnected by Computers. This paper relates the progress of the MAGIC prototype and the lessons learned by the Ogden ALC Contracting Directorate.

Generalized Approach

The goal of MAGIC was to develop an electronic data transfer system with utility. Utility was defined as a system that would reduce contracting processing time, minimize paper in the system, and eliminate repetitive data entry. The system would cull data from existing databases. The prototype would be compatible with, and accessible by, existing and future Air Force data systems as well as contractor systems. The benefits of this strategy were seen as an overall reduction in acquisition lead time, increased data visibility, better logistics management, improved contractor response time, and better integration of data.

The Director of Contracting (PM) at Ogden ALC appointed a small working group in mid-1986 to explore the concept of "paperless contracting." The group was commissioned to bring electronic transfer of contracting data to fruition. The PM group worked with members from the Ogden ALC Directorate of Systems and Communications (SC) as well as with industry representatives. Members of the local chapter of the Industrial Associates of the Air Force represented the interested private sector. Some of the businesses represented were General Dynamics, Martin Marietta, Westinghouse, Goodyear, Frontier Engineering, and McDonnell Aircraft. During these initial meetings, the Industrial Associates elected the Fort Worth Division of General Dynamics to be the prototype contractor for the project. Besides choosing a prototype contractor, the main thrust of these initial meetings was to delineate the parameters of the project and to define specific goals. Existing processes and capabilities identified and investigated were:

(1) Databases (government and contractor).
(2) System interfaces (Local Area Networks - LAN).
(3) Data formats (field lengths, attributes).
(4) Automated purchase requests (J023).
(5) Coordination cycles (government and contractor).
(6) External data communication paths.
(7) Efforts at other ALCs.
(8) Systems experts.
(9) Commercial applications.

The MAGIC concept evolved from two main precepts: (1) the use of prototyping, or "fly before you buy" techniques and (2) abundant use of commercially available software. These themes are not new. They were presented in the 1986 President's Blue Ribbon Commission on Defense Management report by Mr. David Packard. (7:50-51;57-59;60-62) While the Packard Commission concerned military procurement, its findings can be applied to information systems in general. The Commission recognized prototyping as a proven commercial model worthy of emulation by DOD. (7:51) The Commission observed that many unique military applications could be satisfied with commercial specification items and recommended using commercial products and services, including computer software. (7:61) Certainly the development of database management systems (DBMS) for transmission of logistic data would fit this idea. The concept of developing systems by prototyping with commercial software was discussed in a recent series of trade magazine articles on fourth-generation computer languages (4GLs). (2,4,10) Using 4GLs as a vehicle for prototyping seems natural since 4GLs are designed to increase productivity, and there are a wide variety of relational 4GLs available that support development projects. (2:22,24)

Having decided to use a 4GL to prototype, the Ogden team was next faced with the choice between a relational and a hierarchical 4GL. A relational approach to data manipulation

was deemed to be the most efficient, considering the widely varied applications for the data. Moreover, since the MAGIC data used can be thought of as tables, a relational organization scheme (which simplifies creation of electronic reports and forms) was chosen. A final consideration was that the data required were already in place. A relational 4GL would allow selective access to the existing data. The MAGIC prototype extracts specific data elements to transmit as "electronic forms." The real power in using a 4GL to prototype is that refining the system is a quick and easy task. (10:38) Using a commercial software product also minimizes the maintenance required for the end system. This is not the case for custom programming efforts written in a third generation computer language such as COBAL. For these reasons, the prototype paradigm developed for MAGIC was:

(1) Locate essential data files.
(2) Determine data structure.
(3) Select 4GL software.
(4) Build relational data files.
(5) Construct electronic reports (forms).
(6) Define "electronic mail" paths.
(7) Perform trial transmission of forms.
(8) Iteratively refine the process.

Beyond the requirement for utility, another objective was to use a minimum of new resources. There were only a few people working on the project and little money for specialized programming or hardware acquisition. Data and system security were also of concern. Data elements important to logistic support were shared freely, but system security had to be maintained. Therefore, other more specific objectives were:

(1) Use existing resources (hardware and software).
(2) Employ neutral interface (transportable between systems).
(3) Minimize new programming efforts (commercial 4GL software).
(4) Maximize flexibility.
(5) Assure data confidentiality.

Contract Process

At first the MAGIC project appears to address a simple goal: eliminate paper where feasible in the contracting process. However, one quickly realizes that the "contracting process" at an ALC cuts across several huge, complex and functionally different organizations. At any moment during the acquisition of a given service or item there is a constant flow of information. For example, when an item manager (IM) initiates a request to buy a particular widget, that request is carried forward through the ALC primarily through the use of numerous paper forms. The ALC directorates collect, coordinate, and refine information about the future purchase. When the contracting officer (CO) sends out requests for proposals (RFPs) to industry sources, the communication medium is also primarily through paper forms. The preparation and transportation of these forms require a considerable amount of time and ALC resources. The delays caused by a complex paper-based process increase lead times and costs for spare parts and services. This "paper form" method of data transfer is the norm throughout the industrial base. The ALC can also be viewed as an organization that contains many "islands of automation." The manufacturers and their suppliers also represent their own uncoordinated islands in the industrial base. These "islands of automation" communicate using non-digital (paper-based) media.

The logistics function is, in essence, three major processes: requirements determination and planning, contract solicitation and award, and post-award contract administration. Each of the steps requires data communications within the ALC. Thus, another concern for the project was internal and external communications. Internal communications involve data transfer between the ALC directorates. External communications involve suppliers and other government agencies. Logistics information must be transmitted in accordance with internal (government) and external (industry) standards, as well as in compliance with public laws and regulations.

A complete acquisition data package includes packaging requirements for shipping and the purchase request coordination from the IM to materiel management (MM) engineer and the competition advocate (CR) engineer involving manufacturing restrictions and parts configuration. There is also coordination with the Accounting and Finance Directorate (AC) to verify funds availability and obligation. These data elements and hundreds of others characterize the type of information exchanged. The task facing MAGIC was the transmission of a large volume of related data elements through complex and rigidly controlled organizations. Data accuracy is as critical as the speed of transmission. The first step in the MAGIC prototype was to trace the requirements generation and acquisition process, identify automated processes along the way, and determine the best way to establish data communication paths.

Scope of Project

MAGIC was designed as an iterative prototype that would start with a selected prime manufacturer and evolve to include other selected primes. The culmination would accommodate the numerous smaller contractors. These small businesses are particularly significant because they are the sources of supply for both the prime contractors and the government. The project would begin at the most basic level, a request for quote. As capabilities increased, the project would grow to accommodate all contracting data interchange, which includes all solicitations, requests for proposals, invitations for bids, certified cost and pricing data, small business plans, and finally actual contracts.

Additional enterprises were identified as candidates for the project. These were primarily database functions, as opposed to the data transfer tasks mentioned. The concept was to allow simultaneous access to data by both government and contractors. Real-time data generated during the solicitation process, price history requests, and the publication of current requirements were all to be included. These activities are also currently performed using paper products. Examples of contractor supplied data include accounting data, production control data, and current plant capacity. These shared database interfaces seem particularly important for long-range planning.

Other Initiatives

There are other initiatives, both public and by industry, to stem the flood of paper in the contracting process. In the

private sector, McDonnell Aircraft has developed a system called Support Asset Management System (SAMS) that automates much of McDonnell's business with the Navy in support of fighter aircraft. Another promising effort is at Sacramento ALC. That project replaces the paper purchase requests (PR) with an electronic form. (PRs are the documents that initiate the process of buying a product or service.) As previously noted, PRs are created through complex paths of operations that require many steps in coordination, data entry, correction, and transportation of forms. Sacramento ALC has succeeded in eliminating almost all paper transfer of data during the PR initiation and coordination process. The Sacramento project is called Electronic Purchase Requests System (EPRS) and is the first installment of the Contracting Data Management System (CDMS). The Ogden initiative uses electronic data transfer to bring the electronic PR from the Materiel Management Directorate (MM) into the Contracting Directorate (PM), then on to the contractors and back again. MAGIC proposes to link the requirements determination organization (MM), the contracting organization (PM), and the industrial sector, using electronic transmission of data throughout.

Electronic Data Interchange

Examples of electronic data interchange (EDI) in industry are easy to find. Companies such as Digital Equipment Corporation, Western Union, MCI, and AT&T have been leaders in the electronic mail technology industry for some time (1:18). Examples of corporate use of EDI can be found at General Motors and American Hospital Supply. These companies use their systems to communicate with suppliers to shorten supply lead times and reduce inventories. (3:34) Other companies are suppliers of EDI services: GE Information Services Company (GEISCO), McDonnell-Douglas Information Services, IBM, and Control Data Corporation (3:34) Although EDI is an established industry, some problems remain. When data is exchanged, there has to be a common reference point between systems. In other words, a data dictionary containing the data elements and how they are to be communicated must be established. (5) A commercial carrier such as MCI is responsible for the protocol (communication standards) formalities. Difficulties arise when computer systems need to communicate with each other directly, as there is no accepted standard for EDI. Computers may have different operating systems. Thus, one computer may not be able to interpret data from another computer. Three recent articles on EDI state that standards have been developed. Unfortunately, the standards mentioned in the articles are all different. (5;1:20;3:33) One standard is the American National Standards Institute (ANSI) X.12 standard and the other is the X.400 standard set by the Consultative Committee on International Telephony and Telegraphy (CCITT). Resolution of this problem will spur the growth of EDI systems. Fortunately for the MAGIC project, there were simple solutions to this problem. Ogden ALC, like many other computer intensive organizations, has a wide assortment of mainframe computers. There is also a unique program called the Logistics Data Integration System (LOGDIS).

LOGDIS is a system that allows a user to access data resident in other computer systems. (8:12) LOGDIS also has the ability to "dial out" to other computer systems and receive calls through several modem ports. Moreover, the system is connected to the worldwide Defense Data Network (DDN). The DDN allows a DOD computer to connect to any other computer on the network, regardless of location or hardware configuration. In addition to communications, LOGDIS has a good 4GL relational database package. The MAGIC team determined LOGDIS would act as the central data repository, as well as handle communications between Ogden ALC and the prototype contractor. LOGDIS could prototype both data base and programmed systems; provide data security; and allow easy data communication; and, most importantly, it was already in place.

Identifying Data Files and Paths

MAGIC uses an island of automation, J023 automated purchase system, as its source of purchase requirements. The J023 system was a good starting point because the generation and printing of the PRs were already mechanized. A quick review of the J023 PR process revealed the system generates a "buy signal" and constructs an initial PR. This PR is then reviewed by an IM who corrects any problems. After this review, the J023 prints a final PR that is released to the Contracting Directorate (PM). The MAGIC team decided to "capture" the PR electronically just prior to its final printing. To comply with current procurement rules (about the publication of requirements), only PRs under $10,000 and identified as "sole source" to the test contractor were selected. The captured data was loaded into the LOGDIS computer. One minor problem arose from hardware incompatibility between the J023 and the LOGDIS (which run on a CDC Cyber and a Pyramid respectively). In order to make the file readable, a short program had to be written (in the C language) to convert the storage structure of the file. In addition, the C program selected those PR records applicable to the target contractor. This is the extent of the "hard" programming done by the MAGIC team. This was the first MAGIC bridge between electronic islands of automation. The commercial 4GL database on LOGDIS was used to create a relational table out of PR data elements. The report generating function of the database was used to create electronic forms. It was a simple matter to send the forms to the contractor electronically. At first, complete forms were transmitted from the LOGDIS computer to a personal computer using a conventional 1200-baud modem. The team decided for future operations to send only the data elements and reconstruct the text of the solicitation in the receiving computer. This saved a great amount of time and expense by eliminating transmission of redundant text portions ("boiler plate") of the solicitations. The beauty of this scheme is that the recipient may use any software package to construct the electronic forms.

Pseudo-Expert Systems

The Ogden team was able to use the 4GL programming language to complete some forms that had previously been filled out manually. This did not constitute a true expert system. Nevertheless, a 4GL can perform simple rule-based decision making during data analysis. Future iterations will further investigate using 4GLs to supplement or eliminate manual processes. In addition, the possibility of using commercial expert system shells (which are actually prototype fifth generation languages) is being evaluated.

Two-Way Communications Established

The test contractor responded to solicitations with electronic quotes. Again, only the data points were sent. Boiler plate text clauses were assigned codes, and the codes were included as part of the data. The contractor responded directly to the LOGDIS computer system. The next step was to bring the quote to the government buyer. This was done using a simple data transfer from the LOGDIS computer to the buyers' computer system, the J018. Although the J018 system is a Data General system, there was no problem with file compatibility. The final step was bringing the negotiated procurement from the buyers' J018 system to the automatic contract preparation system (ACPS). The ACPS is another Data General system used to prepare final printed contracts. This sophisticated system is used on a daily basis to construct and print the most complicated contracts. The ACPS operation represents a significant "island of automation" in the contract preparation process. The final steps in the MAGIC project are distribution of the contract to the contractor and contract post-award administration activities. Although, the technology to complete all phases of the project exists, the last two steps have yet to be initiated.

Initial Accomplishments

After being in existence for a short period of time, the Ogden ALC MAGIC effort can list some significant successes:

(1) Adapted LOGDIS system (pyramid).
(2) Located essential J023 data files.
(3) Determined data file structures.
(4) Converted J023 files to relational database.
(5) Used existing database software.
(6) Developed simple "expert systems."
(7) Demonstrated a generic PC interface.
(8) Used concept validation (data link).

It should not be startling news that there is considerable opportunity to improve the logistics acquisition process through the use of EDI. The question is not how to perform the improvements, but whether manpower and money are available. This project has demonstrated a significant capability with a limited application of resources.

Ongoing Objectives

Immediate objectives of the MAGIC program are to continue to develop EDI capabilities following our established iterative model. Specifically, MAGIC will seek to expand capabilities in these areas:

(1) Shared databases.
(2) J018 interface to buyers.
(3) J041 interface to all system requirements.
(4) Internal ALC coordination.
(5) External contract administration.
(6) Upgraded data link speed and capability.
(7) Resolved legal issues.

Most of these areas have already been discussed except legal issues. Some legal questions are relatively simple, such as what constitutes a legal signature. Other issues that are more complicated involve access and ownership of data. Privacy of cost and pricing data is obviously important to the contractor. Access to cost and pricing data requires security. Production data to support material resources planning may not exist. Current production drawings may not yet be in a digital format. It may not be clear when ownership of data transfers from the contractor to the government. When may a prime contractor's digital production drawings be accessed by third party producers? As data processing speed wipes away days and weeks of administrative time, time constraints imposed by the Federal Acquisition Regulation (FAR) and other legislative constraints will become important considerations. The increased use of EDI in the logistics support process may trigger a legislative review of the current rules. These issues and others are currently under review by an AFLC legal team.

Summary

The possibility of using EDI technology to improve the logistics support process at an ALC has been demonstrated. Even though there are significant functional and computer system differences in an ALC, the data systems can be joined to permit rapid data transfer. Data systems at a pilot contractor's facility have responded to electronic solicitations by accessing an ALC "front end" computer system. This has been realized with a minimum of economic and manpower investment, by using a model of prototyping with a 4GL commercial product and existing hardware. Future logistics support systems are being designed at this time, and specific consideration should be given to extensive use of EDI technology. Prime contractors should also plan for the use of EDI with their lower level suppliers. Furthermore, follow-on systems should plan for the increased possibility for computer aided manufacturing (CAM) applications as they relate to production and post-production support. The only real opportunity for true material resource planning will come from the availability and use of shared digital production data. The rapid development of digital production drawings will save production resources and could reduce costs. Access to CAD/CAM data will assist in configuration control and encourage early third party spares production competition. The availability of digital information is the only real opportunity for managing hardware across weapon systems, by grouping items for production that are similar in manufacturing attributes.

MAGIC has been split in half. One half will continue to be administered by Ogden's System Management Branch, PMXD. This phase will use purchase requests generated by the J023 system which fall below the threshold for synopsis. (This threshold is currently $10,000 for restricted acquisitions, but has been raised to $25,000 for Full and Open Competition by FAR 5.101.) Purchase requests meeting these criteria are easily automated, as the information needed to construct electronic solicitations reside in the J023 system. Since the J023 system is designed to generate recurring small dollar buys, many of the PRs generated meet these criteria. After prototyping is complete, the software and procedures developed will be shared with other prime contractors. Several contractors have already inquired as to when they may participate in this timesaving system.

The second portion of MAGIC will be managed by the Air Force Logistics Command's Contracting Laboratory, AFLC/PML, at Ogden. This phase will deal with all types of

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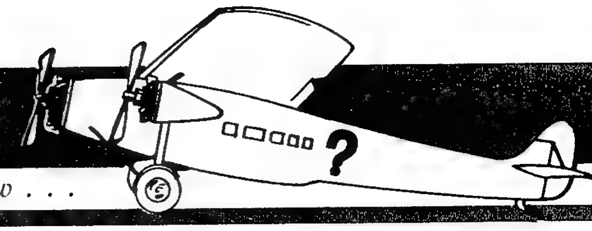

Enquiring Loggies Want to Know . . .

Respondent: General Duane H. Cassidy, Commander, Military Airlift Command, Scott Air Force Base, Illinois

Respondent: Brigadier General John E. Jackson, Jr., Director, Manpower & Organization, DCS/Programs and Resources, HQ USAF, Washington DC

Q. Can the Air Force expect sufficient sealift support in wartime and crisis situations in light of recent Chapter 11 actions by ocean carriers and the lack of availability of maritime ship crews?

A. We're asking that very question, with a DOD intertheater mobility study underway right now. The study addresses sealift and airlift capabilities during emergency deployments, as well as the impact of Chapter 11 actions by ocean carriers and shortages of ship crews.

Q. How has deregulation affected commercial carriers' abilities to perform their CRAF commitments?

A. Not at all. In the nine years since deregulation, the commercial carrier market has seen a great deal of turbulence, with new carriers coming in, old ones departing, and consolidations of many existing carriers. The end result has been a growth of 4% to 6% in US long-range passenger inventory, with an ever-changing list of CRAF carriers since deregulation. However, the airplanes have remained in the CRAF, regardless of who is flying them.

Although not a direct result of deregulation, the post-deregulation environment also features the express air phenomenon. It has added a new dimension to the air cargo industry, highlighted by tremendous growth in long-range freighter aircraft. Today we have 77 civil aircraft with 10.5 million ton-miles per day (MTM/D) capability. By January 1988, we predict 108 aircraft with 13.9 MTM/D capability. At projected rates of growth, we should reach 15.4 MTM/D by 1994.

The future of CRAF is promising; the challenge is to ensure the many improvements stay on track. We will improve the CRAF by integrating all the supporting programs, following guidance in the National Airlift Policy (NSDD #280), signed by President Reagan in June, and the Memorandum of Understanding on the CRAF between DOD and DOT. These programs include CRAF PLUS, CRAF Enhancement, the National Defense Features Program, the Aeromedical Segment, NAPCAP, CRAF C2 Upgrade Program, and other allied support programs.

Q. An improved defense budget during the first part of the Reagan Administration allowed the Air Force to begin work to field some badly needed systems. Many of these new systems require additional manpower. Current indications are that there will be little, if any, additional manpower to allocate to these new systems. Even an internal realignment of manpower would result in a severe impact on other functional areas. How does the Air Force plan to cope with this situation?

A. If the new system must be fielded without end strength increases, "trade-offs" or areas that must be reduced to accommodate growth for the new system must be identified. Generally, past force structure increases have been implemented by the retirement of older systems or at the expense of the support base. The Air Force has not failed to field those systems considered vital to the National Defense, even without end strength increases. But shortages mean that readiness programs must be cut and the burden of meeting day-to-day workloads fall on fewer people. This will place the Air Force in a position of mortgaging the future by eroding the support base. Ultimately, the cost of adding new missions and forces without commensurate manpower must be paid—and that payment will be in terms of poor morale, low retention, inefficient management, higher cost, and a less ready force. To preclude this, manpower planning must play an increased role in the acquisition process. Systems and components are designed for improved reliability and ease of maintenance to reduce the number of personnel required to support those systems through their life cycle. As the systems progress through the various stages of development and acquisition, manpower requirements become better defined and are integrated into the decision process. Estimates are derived through application of existing standards, computer modeling, comparison to similar systems, and projection of anticipated tasks and levels of effort. Those estimates are refined continually as technologies, operational and support concepts, and basing modes are firmed up. As the system competes in the funding process, a program decision package is developed to capture manpower and other resource requirements. Visibility into those resource requirements is then provided as each given system and program competes for

funding priority in the Air Force corporate review process.

The Air Force has three major efforts to increase productivity to offset manpower growth: the Functional Review Process (FRP), the Productivity Enhancing Capital Investment (PECI) Program, and the Commercial Activities (CA) (A-76) Program. The FRP takes given functional areas (Personnel, Finance, Civil Engineering), streamlines the operation to develop the most efficient organization, and sets a manpower standard. Since 1982, over 100 functional reviews have been completed and over 1,800 manpower spaces have been reprogrammed into critical areas. The PECI Program funds equipment buys to reduce labor and other costs. All projects amortize within a specified period, but not more than five years, depending on the program. Since 1977, the PECI Program has produced an average return on investment of 13 to 1 in dollar savings and cost avoidance. Since 1979, the Air Force has considered over 820 activities for possible conversion to contract under the CA (A-76) Program. Nearly 13,000 manpower authorizations have been reduced as a result of converting to contract or streamlining in-house operations. The Air Force has almost 14,000 authorizations currently under consideration for contracting in over 318 activities.

Q. What impact does European Troop Strength (ETS) limitations have on readiness, particularly in the logistics area, and what actions are we taking?

A. The European military troop strength ceiling is a congressional strategy to encourage the NATO allies to increase their share of the total NATO defense burden. The Air Force, like the other Services, has significant ongoing efforts to manage the European troop strength. These include force structure decreases, contracting initiatives, host nation support agreements, civilianization, and other management actions. As a result, the logistics community has been impacted, as have the other functions. Forces are deployed to potential combat theaters to preserve the peace and defend our national interest in response to a threat. When force structure is constrained by a ceiling in lieu of what is required to counter the threat, readiness and sustainability suffer.

Continuation of the European ceiling forces the Air Force to trade off current combat capability or a portion of the essential support base to fund additional needed programs. Priority programs, such as the Ground Launched Cruise Missile (GLCM) and Compass Call aircraft, were offset through force structure deletion, civilianization/contract support, returning some functions to the CONUS, and unit undermanning. The emphasis of Congress has been to increase the conventional capabilities in Europe to preclude the early employment of nuclear forces. However, the effect of the ceiling has, in some cases, lowered the nuclear threshold by forcing reductions in conventional forces (OV-10s and RF-4s) to allow increases in other needed capabilities (GLCM). Our presence in Europe is not only to support our allies but to maintain our national security interests. This ceiling has restricted the military's flexibility to match force composition to the threat.

DOD has proposed legislation to eliminate the ETS ceiling. If this does not occur, the Air Force must continue to seek ways to remain within the ceiling constraints—not only in the logistics areas but in other areas as well.

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purchase requests. The lab may export MAGIC for use at the other air logistics centers. The lab may develop a link between the buyers' J018 system and ACPS. This will allow electronic distribution of contracts as well as online editing of contracts and solicitations by buyers. PML may also develop a link with the EPRS when it is implemented, probably during 1988.

The most ambitious goal of MAGIC is to set up an electronic "bulletin board" of currently synopsized items which could be accessed by all contractors using a microcomputer. Contractors would be able to query this database of items open for competitive bidding and request solicitations online. This phase of the project is contingent on receiving funding for the required computer hardware.

For now, the application of EDI can reduce the amount of time it takes to acquire spare parts and services. As the procurement environment becomes more complex, more reviews and coordinations are required. Much of the acquisition lead time consists of documents waiting for review. The use of EDI can squeeze much of the waiting time out of the process. This possibility can be realized by using existing equipment and commercial 4GL software. Development times are rapid and ownership costs of maintaining the data systems are minimum. Existing data systems and files can be used with little or no modification, even though their design did not anticipate EDI applications. The opportunity exists for achievement of "paperless contracting" through use of a little MAGIC.

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SOLE Logistics Symposium

The 23rd Annual International Logistics Symposium sponsored by the Society of Logistics Engineers (SOLE) will be held August 23-25, 1988, at the Buena Vista Palace Hotel in the Walt Disney World Village, Orlando, Florida. The theme of this year's symposium is "Expanding Logistics Horizons." For information call Patricia Sutherland at SOLE Headquarters (205) 837-1092.

Computing Leaner, Meaner War Readiness Spares Kits

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Currently, the Air Force uses one algorithm to compute war readiness spares kit (WRSK) requirements and another algorithm to assess the kit's ability to support its wartime tasking. If these two algorithms result in different answers, the Air Force WRSK requirements could be overstated or the Air Force could be identifying the wrong items for increased management attention. If the algorithms result in two different answers, which is the *right* one?

We recently compared the requirements cost, backorder performance, and aircraft supportability of the Dynamic Multi-Echelon Technique for Recoverable Inventory Control (Dyna-METRIC) to the current Air Force WRSK Requirements Computation System. The results were revealing—the Dyna-METRIC model computes leaner, meaner war requirements.

In this article, we describe the two systems and explain why Dyna-METRIC computes kits with more combat capability at less cost than the current system. We also show some comparison results for one of the Air Force's frontline tactical fighter aircraft, the F-15. Finally, we describe the Air Force Logistics Command (AFLC) plans to use Dyna-METRIC to compute war requirements.

System Descriptions

We first describe the current system's requirements methodology and then describe Dyna-METRIC. Our descriptions are nonmathematical; those wishing to review the math details should see References 1 and 2.

Current System

The current WRSK Requirements Computation System uses a marginal analysis approach to minimize the weighted average of aircraft not mission capable due to supply (NMCS) and backorders. Requirements levels for all items start with the average pipeline stock (repair pipeline for those items with base repair or average demand over the 30-day period for those items with no base repair). The model then adds stock based on the largest marginal reduction (per dollar) of a weighted average of NMCS conditions and backorders. Thus, the model computes the marginal weighted average reduction of adding one unit for each individual item in the WRSK and selects the largest. It continues this process until it reaches the direct support objective (DSO).

The marginal gain from adding a unit of stock is measured by a weighted average of NMCS and backorders and the weighting varies as the NMCS approaches the DSO target. To illustrate, consider the following formula with weighting factors "X" and "Y":

$$\frac{\text{X (NMCS Marginal Reduction)} + \text{Y (Backorder Reduction)}}{\text{Unit Cost}} = \text{Marginal Gain}$$

As the number of grounded aircraft (NMCS) approaches the DSO target, the weighting factor "Y" gets larger and "X" gets smaller. Therefore, the current system stocks more items which tend to reduce backorders relatively more than items needed to produce aircraft.

As a result, *the current system does not optimize aircraft availability; it does not find the least cost collection of items to meet the aircraft availability target*. However, we should not make any value judgment about the current system because it reduces backorders. Backorders are related to cannibalization actions, and a large number of backorders could mean an unacceptable wartime workload on maintenance. We analyze this assertion later.

Another reason the current system does not match Dyna-METRIC is *the current system does not consider indenture relationships. It treats all items as line replaceable units (LRUs)*. This logic is fine for remove and replace (RR) kits; however, it mis-states the aircraft availability for remove, repair, and replace (RRR) kits. For example, the lack of a shop replaceable unit (SRU) only indirectly affects the availability of its next higher assembly, an LRU. On the other hand, if enough LRUs are stocked, a shortage of SRUs will not necessarily result in grounded aircraft.

Dyna-METRIC

Dyna-METRIC is a RAND-developed model that the Weapon System Management Information System (WSMIS) currently uses to assess the wartime capability of existing WRSK (and base-level self-sufficiency kits). Besides assessments, Dyna-METRIC can also be used to compute requirements. In the requirements mode, Dyna-METRIC minimizes the cost to meet a prespecified probability of having fewer than some prespecified (DSO) number of aircraft grounded over a 30-day period. We make a point of this, because the probability, or confidence level, is an input parameter to Dyna-METRIC. Comparisons of Dyna-METRIC to the current system must consider the confidence level (addressed later in this article). Also, note an upper bound on cost can also be specified when using Dyna-METRIC in a requirements mode.

The Dyna-METRIC model considers indenture relationships; it considers the impact the lack of an SRU has on the LRU and the weapon system. Dyna-METRIC correctly assumes the lack of an SRU will not necessarily ground the weapon system. If an SRU fails and either there is a spare SRU *or* a spare LRU, the weapon system is still operable. Of course, the lack of an SRU has an impact on the availability of its LRU; the LRU cannot be repaired until it has all of its component SRUs available. Thus Dyna-METRIC computes the expected backorder time for SRUs and adds that to the expected repair pipeline time of the LRU. This extra waiting

time is called awaiting parts (AWP) time and extends the LRU's average pipeline time. Thus, *Dyna-METRIC more closely models the actual repair situation*. Currently, Dyna-METRIC does not optimize the SRU/LRU trade-off; it does not determine the least cost mix of LRUs and SRUs to satisfy the weapon system goal. However, it does accurately consider the SRU's impact on the LRU and, therefore, the weapon system.

In addition to the indenture relationship, Dyna-METRIC offers other advantages when compared to the current system. Dyna-METRIC can consider limited funding. This capability can be used to compute the best mix of items to buy with limited funds. In today's system there is currently no way to determine what spares in the total requirement will yield the most aircraft and which, therefore, should be bought first. Dyna-METRIC's capability can be especially useful as funding for war spares becomes increasingly scarce—a situation we currently face.

In summary, Dyna-METRIC appears to better model the wartime demand and repair environment and it correctly models indenture relationships. The next question is: How do its requirements computation results compare to the current system's results?

Comparison of Dyna-METRIC to the Current System

We compared Dyna-METRIC to the current system using the same demand and repair data used for computing existing kits. Table 1 shows the results for the computed items (noncomputed items are excluded) for an F-15 kit. The results reflect a Dyna-METRIC assessment of the kit, the same assessment currently used in WSMIS to assess WRSK for a 30-day wartime scenario.

COMPARISON OF DYNA-METRIC TO THE CURRENT SYSTEM F-15 (24 PAA KIT) (DSO = 6)

METHOD	DAY 30 GROUNDED AIRCRAFT	30-DAY CUMULATIVE BACKORDERS	COST (MILLIONS)
A. Current System	4.9	77.6	$ 35.5
B. Dyna-METRIC (Without a pipeline floor)	5.7	515.6	$ 21.6
C. Dyna-METRIC (With a pipeline floor)	5.5	167.7	$ 26.1

Table 1.

Table 1 shows that, under the current system, the Dyna-METRIC assessment model expects 4.9 aircraft grounded on Day 30. This meets the DSO of no more than 6 aircraft grounded. Also, over the entire 30-day war period, 78 backorders are expected. The total requirements cost of the computed items in the F-15 kit is $35.5 million. Recall the current system stocks at least the pipeline floor in the kit. We present the results of two Dyna-METRIC computed kits, one without a pipeline floor (Method B) and one with a floor (Method C). *Both meet the DSO and cost much less than the current system kit;* however, there are considerably more expected backorders. Backorders are related to the number of cannibalizations and, therefore, the workload on maintenance. We compared the expected flight-line cannibalizations per day for the 30-day war scenario for the current system and the two methods (B and C) of the Dyna-METRIC computed kits in Table 1.

The Dyna-METRIC kit (without a pipeline floor) required at most 20 more canns (on Day 5) per day than the current system, thus generating a considerable extra workload on maintenance. However, the Dyna-METRIC kit, which included the pipeline floor, required at most 4 canns more per day than the current system kit. *Dyna-METRIC computed kits with a pipeline floor significantly reduce the amount of maintenance workload* (as measured in canns per day) *when compared to Dyna-METRIC kits without a pipeline floor.*

Next we compared the range and depth of current system kits to the two Dyna-METRIC kits (Methods B and C) from Table 1.

RANGE AND DEPTH SUMMARY (F-15)

METHOD	RANGE LINE ITEMS	DEPTH (UNITS)	DIFFERENCE FROM CURRENT SYSTEM RANGE	DIFFERENCE FROM CURRENT SYSTEM DEPTH
A. Current System	565	2047	–	–
B. Dyna-METRIC (No Floor)	216	705	349	1342
C. Dyna-METRIC (With Floor)	325	1102	240	1165

Table 2.

Dyna-METRIC significantly reduces the size of the kit. Dyna-METRIC eliminates many of the 1 and 2 leveled items from the current kit and reduces the number of units of many SRUs. The F-15 is an RRR kit and, therefore, the current system stocks too many SRUs. As is evidenced by Tables 1 and 2, the current system stocks items that reduce backorders, but do not increase aircraft availability. As we discussed earlier, the current system does not consider indenture relationships; therefore, it erroneously assumes that the lack of an SRU grounds the weapon system. Thus, the current system kit includes SRUs that Dyna-METRIC does not include.

AFLC Implementation Plans

The previous section indicated there were significant benefits from using Dyna-METRIC to compute WRSK. However, Dyna-METRIC requires two assumptions not required by the current system. In this section, we discuss the two assumptions: pipeline floors and confidence level. In addition, we describe our plans to use Dyna-METRIC to compute WRSK in the WSMIS Requirements Execution Availability Logistics Module (REALM).

Pipeline Floor

The issue is: "Should Dyna-METRIC include the pipeline floor?" Remember the current policy is to stock at least the average demand during either the repair pipeline (if the item can be repaired) or the entire 30-day (pre-replenishment) war period. Note from Table 1 that while there is a cost difference in Dyna-METRIC when a floor is included, including a floor reduces backorders and, therefore, cannibalization actions.

Table 2 shows including the floor increases the number of line items and units compared to without the floor, but *the Dyna-METRIC kit is still much "leaner and meaner" than the current kit*. In short, including the pipeline floor does not cost much and decreases the number of cannibalizations required. We think reducing maintenance's workload and providing extra stockage protection is well worth the minimal cost increase. We propose Dyna-METRIC retain the pipeline floor.

Confidence Level

A second input Dyna-METRIC needs to compute requirements is the confidence level, which is the degree of confidence (probability) of meeting the DSO. The decision of which confidence level to use is not an arbitrary one; increasing the confidence level increases the kit's performance but it also increases the cost.

We compared the current system's confidence levels and performance to Dyna-METRIC's performance with an 80% confidence level for both RR kits (Table 3) and RRR kits (Table 4). Note in Tables 3 and 4, we used a DSO of 4 (out of 24 aircraft), because we concluded our analysis prior to the change to a DSO of 6.

DYNA-METRIC VS CURRENT SYSTEM CONFIDENCE LEVEL COMPARISON RR KITS

AIRCRAFT	METHOD	CONFIDENCE LEVEL	DAY 30 GROUNDED AIRCRAFT	TOTAL EXPECTED BACKORDERS	COST ($M)
C130 (8PAA)	Current System	.51	1.8	20	$ 2.7
	Dyna-METRIC	.80	1.2	26	$ 2.7
C130 (16PAA)	Current System	.78	2.9	30	$ 3.7
	Dyna-METRIC	.81	2.9	83	$ 3.0
F-16 (24PAA)	Current System	.58	4.6	40	$ 16.8
	Dyna-METRIC	.80	3.8	87	$ 16.2
A-10 (24PAA)	Current System	.61	4.4	30	$ 8.3
	Dyna-METRIC	.80	3.7	47	$ 8.7
B-52 (14PAA)	Current System	.68	2.4	10	$351.0
	Dyna-METRIC	.80	2.4	42	$351.0

Table 3.

Note from Table 3 that Dyna-METRIC does not reduce the cost for RR kits, although it does provide a higher confidence level of meeting the DSO. Most of the benefit of using Dyna-METRIC results from the accurate consideration of indenture relationships. For RR kits, there are little or no SRUs, hence Dyna-METRIC computes kits similar to the current system.

DYNA-METRIC VS CURRENT SYSTEM CONFIDENCE LEVEL COMPARISON RRR KITS

AIRCRAFT	METHOD	CONFIDENCE LEVEL	DAY 30 GROUNDED AIRCRAFT	TOTAL EXPECTED BACKORDERS	COST ($M)
F-15 (24PAA)	Current System	.71	4.1	52	$ 59.5
	Dyna-METRIC	.80	3.7	44	$ 44.3
F-111 (18PAA)	Current System	.82	2.5	11	$108.6
	Dyna-METRIC	.80	2.8	31	$100.9

Table 4.

Computing WRSK requirements with Dyna-METRIC and 80% confidence levels provides better support (increased confidence of meeting the DSO) at equal cost for RR kits and at less cost for RRR kits. We suggest Dyna-METRIC use 80% confidence levels to compute WRSK.

The Next Step

AFLC has included the Dyna-METRIC model as part of WSMIS/REALM. In March 1988, AFLC began transitioning to Dyna-METRIC by computing WRSK requirements for the F-16, F-111, and F-15. Barring unforeseen problems, the use of Dyna-METRIC to compute WRSK requirements will be extended to other types of aircraft during the Fall 1988 WRSK review cycle. This is a significant step forward. The Air Force will be able to field kits with equal or better combat capability at less cost than the current kits. But this is really just the beginning. The folks at AFLC are now developing smart ways to achieve even more combat capability and reduce the costs even further. We are prototyping ways to use Dyna-METRIC to: (1) determine what spares to buy with limited WRM dollars, (2) compute leaner, meaner BLSS levels, and (3) further reduce WRSK costs by optimizing the mix of LRUs and SRUs. It is an exciting time to be in the requirements business and the Air Force Logistics Command is committed to developing innovative ideas to compute war requirements to fly, fight, and win!

References

1. AFLCR 57-18, *Management and Computation of War Reserve Materiel (WRM)*, 21 April 1986.
2. Pyles, Raymond. *The Dyna-METRIC Readiness Assessment Model: Motivation, Capabilities and Use*, RAND, Santa Monica, CA, 1984.

Paint Primer Proves Perfect

After only six months of a planned two-year study, the Air Force has approved a new primer for use in painting C-5A Galaxy cargo aircraft.

The polyurethane primer, known commercially as Koroflex, is more flexible and crack-resistant than the old coating. Developed in 1984, Koroflex was previously tested on B-52s. The result was a 20% to 70% decrease in the level of corrosion on the bombers. In addition, frequent touchups will be eliminated and, since Koroflex is made up of one component, mixing is not required. Savings will also be realized through longer primer life and reduced corrosion on the C-5A.

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New Concept in Contractor Support: Assured System Availability

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As a logistician, I cannot think of a situation more frightening than to deploy a new weapon system and not be able to support it. Unfortunately, the history of our services is replete with examples of just such conditions. Recently, Air Force Logistics Command (AFLC) and Air Force Systems Command (AFSC) jointly developed and instituted an advanced concept of contractor support, "assured system availability" (ASA). Simply put, it is a comprehensive approach to ensure a system is supportable when we, the government, assume organic support responsibility. For those who know something of Air Force contractor support concepts, this may sound like "interim contractor support" (ICS). It is! But, it is much more than that. This article will briefly explore the development of ASA and its purpose. More specifically, it will describe, in some detail, the key features of this concept. And, finally, it will raise a few concerns about ASA and its application.

Before proceeding, it is important that we understand what is meant by the word "system." According to AFR 65-3, *Configuration Management,* a system is:

> A composite of items, assemblies, skills, and techniques capable of performing and/or supporting an operational (or nonoperational) role. A composite system includes related facilities, items, material, services, and personnel required for its operation to the degree that it can be considered a self-sufficient item in its intended operational (or nonoperational) and/or support environment.[1]

"Nearly every system fielded has or will use some form of temporary contractor support."

Therefore, according to this definition, one does not have a system unless the necessary logistics support resources are also available. For the purpose of this article, the term "end item" will be used when referring to the primary resource being supported, such as an aircraft, ship, or missile, and the word "system" when meaning the end item and its total logistics support structure.

Background

The temporary use of contractors to support deployed systems, while waiting for fielding of the organic support capability, has been a standard practice in all services for years. Generally known as ICS, it has virtually become a fact of life. Nearly every system fielded has or will use some form of temporary contractor support until its total organic capability is in place.

When individuals stop to consider the length of time involved in some ICS contracts, they begin to wonder if temporary is the appropriate descriptor to use. A few of the systems, along with the amount of ICS time, still using some degree of temporary contractor support, are:

B-52 Offensive Avionics	5 yrs
KC-135R	6 yrs
A-10 Inertial Navigation System	7 yrs
EF-111A	9 yrs
F-16	10 yrs

Because of situations like these, better ways to manage and control ICS were needed. So, in February 1986, an AFLC/AFSC panel was formed and began work on this problem. The result was ASA. Needless to say, the concept went through numerous reviews and much debate before it was eventually approved by the Vice Chief of Staff, USAF, in November 1986. As of today, according to HQ AFLC, the advanced tactical fighter (ATF), small intercontinental ballistic missile (ICBM), advanced technology bomber (ATB), and the C-17 have been selected as the first programs to apply the ASA concept.

Purpose

As mentioned, ASA is an approach to initial support of newly fielded systems. One of its major objectives is better integration of the ICS contracting effort in both the full-scale development (FSD) and production contracts. In addition, ASA:

(1) Gives the program manager the responsibility and resources to support the system until an organic logistics capability is developed.

(2) Defers development of the logistics support infrastructure until the design stabilizes.

(3) Tasks the contractor to provide initial system support at specified availability levels.

(4) Contractually incentivizes the contractor to obtain organic capability as soon as possible.[2]

Concept Description

First, a key point that must be mentioned is that the detailed tactics espoused in the ASA concept were not developed as a rigorous set of rules to be explicitly followed. But, rather, they are intended to be a set of guidelines proportioned to the unique characteristics of each program.

To ensure that the tenets of the ASA concept are understood and properly applied, program managers for candidate programs are required to prepare an implementation plan outlining their approach to ASA. The plan will be reviewed and coordinated by a panel comprised of the using command, Air Force Acquisition Logistics Center (AFALC), the AFLC system program manager (SPM), key program office

personnel, and any other appropriate organizations. The plan will then be forwarded, along with panel recommendations, to HQ AFSC and HQ AFLC for approval. Next, HQ AFSC/AFLC will jointly summarize the plan's content to HQ USAF, who will make the final decision on the application of ASA for that specific program. It is anticipated that after the ASA concept becomes sufficiently well known throughout the acquisition community, program managers will not need to prepare an implementation plan. Future ASA planning will be integrated into the basic acquisition process and existing planning documents.

Criteria and Cost/Benefit Analysis

ASA is not for every program. It is targeted for those new acquisitions or modification programs that are:

(1) Concurrent (FSD/production overlap), fast-paced programs employing new or "high tech" technology.

(2) Expected to have design instability during initial fielding.

(3) Intent on having an organic support capability.

(4) Expected to use or need temporary contractor support.

(5) Able to apply ASA strategies in the FSD/production contracts.

(6) Managed by the Air Force as the executive service.

(7) Employing a competitive acquisition approach (desirable).[3]

Not only should a program satisfy these criteria, but it should also receive sufficient benefits from its use to justify the cost. It is the program manager's responsibility to perform a cost/benefit analysis in cooperation with the AFLC SPM to determine if ASA is, in fact, cost effective. This analysis should be a comparative evaluation of the costs versus benefits of using ASA instead of other strategies such as those employed under earlier applications of the ICS concept.

Key Milestones

Two significant milestones are associated with the ASA concept: the declaration of "design stability" (DS) and the accomplishment of the "support system verification" (SSV). (See Figure 1 for a time-line depiction.)

Per concept definition, design stability is "that point when an item no longer requires additional engineering and testing in order to meet initial delivery design specification requirements for operational performance, producibility, maintainability, or reliability." To satisfy this definition, critical design reviews and qualification testing should have been completed and sufficient testing (developmental test and evaluation and, to the extent possible, initial operational test and evaluation) performed to substantiate a reasonable assurance of performance. Normally, design stability will occur at the physical configuration audit.[4]

Because provisioning, the development of technical orders, the design of support equipment, and other related logistics resources are affected by an end item design stability, it is necessary to establish design stability target dates. These dates are used in planning and contracting for acquisition of the needed logistics resources. Design stability dates are generally proposed by the contractor in the FSD proposal and negotiated during source selection. The dates can be made contractually binding or can be implicitly set by contractually establishing a support system verification date. Design stability can be established for a system, subsystem, or individual component

SAMPLE ASA TIMELINE

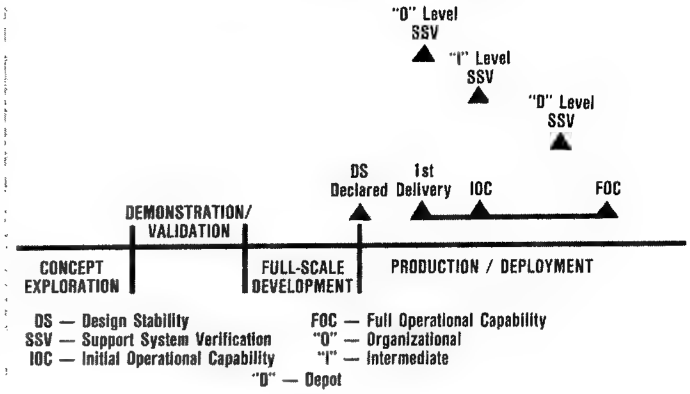

Figure 1.

item. One recommended way of declaring design stability would be through the use of the configuration control board (CCB), who would, upon declaration, issue a CCB directive that would signal the start of the logistics support system development effort for an item declared design stable.

There is no question that design stability is a vital necessity when developing and fielding a logistics support system. Without it, as the design of the end item changed, so too would many of the logistics support elements. This kind of activity simply costs more money and can actually further delay attainment of an organic support capability. By the way, the same attention to design stability should be given support equipment and training devices (trainer/simulators), for like the major end item, they too have a logistics support system.

Equally important as design stability is the function of SSV which is:

> a process for formally confirming that organic capability has been attained and that all the following elements are available:
> (1) Verified technical manuals.
> (2) Approved/operational peculiar support equipment.
> (3) Trained maintenance personnel.
> (4) Training program and courses.
> (5) New/peculiar spares provisioned, ordered, and on the shelf.
> (6) Facilities.
> (7) Software maintenance capability.[5]

The declared design stability of an item coupled with lead time requirements for support system development will result in establishment of an SSV target date(s). The SSV target date is jointly developed through agreement between AFSC, AFLC, and the using command, and can be established on a subsystem or line replaceable unit (LRU) basis as well as by level of maintenance (base and depot). This SSV date is significant because then organic capability has been attained. It is also the date when the program manager and contractor are usually no longer responsible for the supportability of the subsystem or LRU that has a confirmed SSV. SSV dates and planning strategies cannot be treated in isolation. They must be a part of and considered during the site activation, system turnover, and program management responsibility transfer planning processes, for they all will be directly affected by having or not having organic support.

DS and SSV are the bedrock for ASA planning. However, there are other elements of the concept that must be mentioned. ASA has established as "goals" the attainment of organic maintenance capability at the organizational level by

the delivery of the first end item and at the intermediate level by the initial operational capability (IOC) date. Though the ASA concept has not established a goal for depot level maintenance, it does not preclude a system program from establishing one. In fact, we are currently spending more money and time on depot level contractor support than any other level of maintenance. This is due in part to the traditional progression in establishing an organic maintenance capability—first organizational, then intermediate, and finally depot. Keep in mind, though, that SSV goals are just that—goals. Design stability is the key driver in determining when the effort to develop an organic capability should commence. Actual organic capability timing is program dependent and must be negotiated with the using command.

> *"Contractual incentives could be the most important aspect of the entire ASA concept."*

Business Strategy and Contract Application

Under ASA, the support contractor is responsible for supplying services necessary to maintain peacetime operating capability, as well as wartime tasking (mobility kits, increased sortie generation, exercises), until we have organic capability. But, we also want to motivate manufacturers contractually to provide a stable design and strive for organic capability at the earliest possible time. Quite possibly, contractual incentives could be the most important aspect of the entire ASA concept. It is these incentives—be they monetary or nonmonetary, positive or negative—that will usually have the most influence on the contractor to reach and sustain the required level of system availability, and at the same time they also provide the motivation to reach organic capability.

During ASA planning, the relationship between the FSD and production contracts and contractor support obligations must be handled as an integrated effort. It is the FSD and production contracts that task the contractor to develop technical orders, design support equipment, prepare provisioning documentation, and provide all the other logistical necessities. It is this same contract that establishes delivery schedules for those items. However, it is the ASA contract tasking, be it part of the FSD/production contracts or a separate contract, that delineates contractor support responsibilities until organic support is realized. The ASA contract should be flexible enough to allow for variations in production quantities ordered and delivered, single or multiple sight support, and the impact of product performance agreements (warranties and guarantees) on cost, availability rates, and maintenance responsibility. Contractually, the concept reaps the greatest benefits when competition exists and the FSD contract includes production options.

As for budgeting, ASA will continue to use existing USAF and AFLC policy, with most of the costs charged to the Operating and Maintenance (3400) appropriation. Investment spares used during the contractor support period will be paid for using AFLC initial spares dollars.

Data acquisition to support the ASA concept does not differ markedly from that obtained under the existing ICS approach. Basic data needs would include:

(1) Status of contractor progress against contract deliverables.
(2) Maintenance data collection (AFTO Form 349).
(3) Report of assets.
(4) Consumption reports.
(5) Software documentation update reports.

Management

As previously stated, it is the program manager's responsibility to contract for ASA and provide the necessary support to fielded systems until organic capability is attained. Because the issue is one of logistics support, the authority for ASA planning will likely be passed to the Deputy Program Manager for Logistics (DPML) or Integrated Logistics Support Manager (ILSM) for that program. Notice, I said authority. The responsibility for obtaining the logistics resources and for providing contractor support until the organic resources are available remains with the program manager. In any program of significant size, the DPML/ILSM should form and chair an ILS Management Team (ILSMT). This team, made up of specialists in the various logistics disciplines as well as other organizational representation, should do much of the development, implementation, and management of the ASA strategies and tactics. A key member of the ILSMT is the SPM. The SPM is assigned to the HQ AFLC designated prime air logistic center (ALC) for the system. It is this prime ALC that will eventually be given the final responsibility for support of the system for the bulk of its deployed life. It is, therefore, of paramount importance that the SPM and others from the supporting command be brought in on the ASA planning process as early as possible. Also, remember, since the DPML/ILSM works for the program manager, the program manager should always be kept apprised of and have final approval over the ASA approach to be employed.

Comments and Concerns

ASA is a tremendous step forward in improving the way we support systems on an interim basis. It gives greater emphasis on motivating the contractor to attain organic capability, and it allows for a smoother transition from contractor to organic support.

This portion of the article has been included for the sole purpose of putting on paper a few concerns and questions that went through my mind when I first read the concept. These concerns and questions are meant to stimulate further thoughts on the process by those programs which anticipate use of the concept and not to identify shortcomings of the process itself.

The first concern deals with the declaration of design stability at the time of the physical configuration audit (PCA). The preceding ASA concept description mentioned that design stability is generally declared around the time of the PCA and that logistics support for subsystems or LRUs should not be developed until an item is design stable. Many programs conduct their PCA on one of the very first production articles. If this is done, there is not much time between PCA and deployment to develop and field the logistics support for the system. I fully concur that logistics support resources should not be developed before an item is reasonably design stable. However, overprecaution (waiting till each item is 100% design stable) may be equally detrimental to the cost and timeliness of fielding logistics support. Therefore, I suggest that each program employing ASA take a hard look at when

design stability for an item should be declared. It seems logical that if an item was deemed important enough to be identified and managed as an individual configuration item, that design stability should be declared on an item-by-item basis. I do not think we want to set a single program milestone, like PCA, as the point in time when we start development of logistics resources. But, rather, we should have design stability declared when we feel a reasonably comfortable level of confidence in design stability exists. This confidence level could be reached as early as the critical design review or as late as after deployment.

My second area of concern deals with support system verification. Again, according to the ASA concept description, in order to have SSV, a series of resources must be available (spares, support equipment, technical orders). My questions are:

(1) Who does the verification—the SPO, user, AFLC, a composite team?

(2) Is the verification an actual visual accounting of the various resources at the base or depot and does it include operability and serviceability of the resources?

(3) Is SSV contingent upon the availability of a support system for the support system? (If we are going to do organic repair of support equipment, must the technical orders, spares, facilities, support equipment, and trained manpower be available for that capability before SSV has been reached?)

The final concern deals with support in combat. As mentioned earlier, ASA can be used to specify a wartime tasking responsibility on the contractor for such things as increased sortie generation, exercises, and mobility kits. My interest in combat support was peaked while recently reading the minutes of a House of Representatives Hearing on contractor support of weapon systems overseas during hostilities. A major portion of the testimony was given by persons from the Government Accounting Office (GAO). The GAO raised issue over the lack of assurance that civilian employees (government or contractor) would continue to perform their critical maintenance functions should hostilities be imminent or in progress. When queried about the presences of "war clauses" in support contracts, the GAO responded:

> In the contracts we reviewed, which support U.S. forces in Europe, we found only six had 'war clauses' which require the contractor to continue to provide service during a crisis. None of the six contracts with war clauses were for support of weapon systems. We do not know if such clauses have ever been used in contracts with companies providing direct maintenance and repair of weapon system components.[6]

It was, however, made clear in further GAO testimony that at the time of their study several critical systems were in part, if not totally, under contractor support at bases in Europe (worldwide military command and control system, F-15 electronic countermeasures (ECM), and radar warning receiver).[7]

In response to still another question on contractual war clauses, the GAO commented: "Many contractor personnel were not aware of what their responsibilities would be in a crisis situation. Many thought that they would be expected to leave."[8] The GAO estimated there were between 4,500 and 6,000 positions manned by civilian personnel that are considered essential to the USAFE wartime operation. Under current law, essential civilians cannot be required to stay on their job during mobilization, hostile action, or an undeclared war. DOD civilians and contractor personnel may remain in, or be sent to, unsafe areas overseas only on a voluntary basis. The Uniform Code of Military Justice extends court-martial jurisdiction to civilians accompanying or serving with armed forces who fail to perform duties or obey orders during time of war. However, this has been interpreted by the US courts to mean only a war declared by the Congress and not military action, such as Vietnam.[9]

One particular comment in the GAO's final report particularly caught my eye. In the study's Statement of Objective, the GAO remarked: "We did not include those civilians who help to introduce new systems and equipment, because the requirement for their services is generally temporary."[10] They were obviously referring to the use of some form of ICS. If the ICS is for depot level maintenance and it is done in CONUS, we are generally not too concerned, since most of us consider the US a "safe haven" from attack. Though, even that point is open for debate in some circles. However, if the temporary contractor support is at the base level and that base is in or near a potential "hot spot," it becomes quite a different matter. As eluded to earlier, we, even now, have combat systems under "temporary" contractor support that have been in that situation for many years. The point is simple. As temporary as the contractor support may be intended, hostilities can start at any time. Provisions must be made in any support contract, be it for temporary or lifetime support, for a contractor's commitment to provide continued support should such contingencies arise. Otherwise, the result may be disastrous.

Summary

Because of the natural sequence of events in system design, development, fabrication, and fielding, the acquisition process can deliver hardware usually before it can deliver support. As a result, all the desired or planned support may not be there when we field the primary item. We try to counter this dilemma through the use of temporary contractor support. It has generally worked well, but we have had some problems. The assured system availability concept, an advanced hybrid of our existing interim contractor support approach, should radically improve the effectiveness of contractor support and the subsequent transition to an organic support capability. ASA has placed ever greater importance on the evaluation and declaration of design stability, the verification of the existence of the support system, and the increased use of incentives for end item availability rates and ultimate transition to organic support. The key to ASA success is cooperative planning, a working knowledge of the concept, a properly balanced application of its precepts, and continual oversight of contractor efforts.

Notes

[1] AFR 65-3, *Configuration Management*, 1 July 1974, p. A-3.

[2] *Assured System Availability: Concept of Operation*, 10 March 1987, p. 4.

[3] Ibid., p. 5-6.

[4] Ibid., p. 6.

[5] Ibid., p. 7-8.

[6] Minutes of the Hearing Before a Subcommittee of the Committee on Government Operations, House of Representatives, 98th Congress, second session, *Civilian Support of Defense Department Weapon Systems During Hostilities*, 14 Mar 1984, p. 39.

[7] Government Accounting Office Report to the Secretary of Defense, *Ensuring Retention of Essential Civilians Overseas During Hostilities*, 14 March 1984, Appendix I, p. 9.

[8] GAO Report, *Civilian Support of Defense Department Weapon Systems During Hostilities*, p. 42.

[9] GAO Report, *Ensuring Retention of Essential Civilians Overseas During Hostilities*, Appendix I, p. 1-2.

[10] GAO Report, Appendix II, p. 18.

Software Estimation Factors and Techniques

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This research is intended to give logistics managers an overview of current methods of software estimation and an appreciation of the limitations of those methods.

Introduction

Over the past few years, logisticians have come to see computers as an attractive alternative for problem solving. Advances in computer engineering and tremendous reductions in the size and costs of computer components are making the devices technologically and economically feasible in many new areas.[1] However, meeting real-world requirements for functional Air Force systems takes more than inexpensive hardware. It also takes good quality software. In fact, it is the coded instructions—or software—written to solve specific problems that make computers useful in practical situations.

Since software is critical in satisfying the growing demand for computer services, the ability to plan software projects and accurately estimate the time and resources needed to develop software is a necessity. Unfortunately, at present, software engineering is more akin to a craft than a scientific discipline.[2] Programs are painstakingly handcrafted, at considerable expense, to meet the requirements of one or more users. Attempts to build models for software estimation have had only limited success. Collecting and analyzing historical data has also proven to be difficult. As a result, estimates of software development requirements have been far less reliable than estimates used routinely in other engineering disciplines.[3]

Critical Factors in Software Estimation

The purpose of software sizing or estimation is to provide senior-level managers with estimates of the costs and amount of effort needed to develop a program to meet specific requirements. A very basic software sizing model might look something like Figure 1.

Basic Software Sizing Model

$$\text{Completion Time} = \frac{(\text{size of program} \times \text{program complexity})}{(\text{number of programmers} \times \text{productivity per day})}$$

Figure 1.

This formula may look simple, but looks can be deceiving. Validating such a model would be very difficult. Just coming up with numbers to "plug into" this formula is hard enough, because the critical variables are not well defined. Several methods for measuring program size exist, and program complexity is dependent on many interrelated factors.[4] Computing resources required for development of a program is further complicated by the nature of the resources involved, the nature of the process itself, and communications problems.[5]

The primary resource used in producing software is man-hours. However, programmer skill is difficult to assess. Evaluations tend to be subjective, partly because of the lack of agreement on what is a "good" program and what is not. A RAND study that attempted to use a standard criterion to measure performance objectively pointed out wide differences in programmer productivity:

> Even for the same task, differences between individual programmers can be enormous. In an experiment to evaluate the differences between time-sharing and batch programming, Sackman gave the same two problems (called Algebra and Maze) to a group of twelve programmers having an average experience of 6.5 years. He found that the extreme differences between the programmers' performance on the same task swamped any differences that might have been due to different production methods.[6]

In the study described, the number of instructions written to solve the "Algebra" problem varied from 1,460 to 29,950. Instructions used for the "Maze" problem varied from only 3,900 to a high of 95,300. In other words, one programmer took 25 times the lines of code to solve the problem that another used.[7]

Many of the problems with development are the result of insufficient preliminary study phases. Others are caused by the abstract nature of software. When a project is in the initial stages, it is very difficult to determine exactly how many iterations will be required to complete a specific module or when the next task will begin.[8] Uncertainty could be reduced somewhat by developing standard interfaces, programming methods, and procedures; but this has not been done. As a result, each program module must be laboriously custom designed, programmed, and tested. Even though commercial software has been written since the mid-1950s, the concepts of standard programming methods, procedures, and interfaces still sound revolutionary.[9]

Experience in other areas shows the importance of these concepts. The efficacy of the automobile assembly line is taken for granted because the process is well defined, the workers understand their roles, and all necessary resources are organized in a manner that facilitates production. On the other hand, in software development, the problem to be solved is seldom well defined, programmers disagree about programming methods, and management is often lacking.[10]

Another part of the estimation problem may result from the increasing complexity of the systems we are trying to build. In a recent article, Brooks postulated:

> The conceptual structures we construct today are too complicated to be specified accurately in advance, and too complex to be built faultlessly....[11]

The best tools to cope with complexity are a good baseline and a database of lessons learned from previous (similar) projects.[12]

Doty Associates developed a list (Table 1) of "factors which are considered to have a significant effect on software development manpower requirements, productivity, and cost...."[13]

Development Factors

Performance Specifications	Program Management
Special displays	Development schedule
Data management	Communications
Definition of operational requirements	
Changes in operational requirements	**Development Environment**
Interface to design	
Response time requirements	Developer using another activity's computer
Time (on hardware) constraint	Programmer access to computer
Memory (hardware) constraint	Operational site development
First development on a computer	Development and target computer different
Concurrent development of hardware	Number of different locations
Time CPU specified in schedule	Programming environment
Requirement for innovation	Support software
Language requirements	Programming facilities
Quality requirements	
Reliability requirements	**Production Environment**
Testing requirements	Multiple software utilization sites
Transportability requirements	User interface and participation
Maintenance requirements	End user requirements

(Doty Associates, Inc., 1977)

Table 1.

The last critical factor is communication between users, designers, programmers, project managers, analysts, and many others. The essence of software is an approach toward solving a problem, so the designer's concept must be very carefully and faithfully transferred to all parties involved in developing sizing estimates of the project.[14] Since the concept is abstract, and may be difficult or impossible to represent as a physical model, communication can be a big problem. In addition, the more people involved in the effort, the more work must be put into explaining to them what must be done, and how it should be done.

> If there are n workers on a project there are $n(n-1)/2$ interfaces across which there may be communication, and there are potentially almost 2^n teams within which coordination must occur.[15]

Approaches to Software Sizing

As we have shown, estimating the cost and man-hours needed to develop a program before it is written is difficult, but essential. While there is no single, foolproof way to estimate costs and man-hour requirements, measures like "lines-of-code" are commonly used to facilitate understanding and comparisons of the size of various programs. Although the factors previously mentioned must be included in the equation, program size is the basis for most estimation models.[16]

The process of estimating program size normally begins with decomposition of the program into relatively small, understandable modules. As a rule, these modules will contain 50-100 lines of code that perform a single function or a small number of related functions. Several decomposition techniques have been developed, but process or task based methods are most frequently used. Among these methods, Work Breakdown Structure is promising. It organizes project activities into two types of hierarchical structure. One structure depicts the precedence of software development activities needed to complete each module and the overall system. The other structure is used to show how the software modules fit together in the software system.[17]

Once the system has been decomposed, man-hour requirements and complexity measures are developed for these low level modules and multiplied with a personnel productivity factor to achieve an overall estimator.[18] Estimators like "man/months" are common because they express the amount of effort required for development in understandable terms.

According to a 1980 study of 21 software estimating techniques conducted by Hughes Aircraft Company for the Air Force Wright Aeronautical Laboratories, these methods generally fit into one of three categories. The first is the sideways or "analogy" approach. The next is the bottom up or "element estimate approach," and the last is a top-down approach which employs cost estimating relationships (CERs).[19]

Analogy Method

The analogy approach involves comparing the current project with similar projects completed in the past or currently in progress. This method assumes accurate baseline data on previous projects exist, but this assumption may be incorrect. Doty Associates reported:

> PARMIS Data received from the AF Data Systems Design Center [now Standard Systems Center] contained baseline estimates of costs and actual expenditures, the type data considered important to the study. However, it included inconsistencies and appeared so unique, it was discarded. Over 85 percent of the programs reported, all of which were developed at the installation, did not exceed budget estimates. This situation made the original estimates suspect.[20]

If adequate data exist, they must be carefully reviewed and figures adjusted as necessary. Adjustments are based on experience and comparisons between baseline data and data for the current project. This process can be accomplished by an individual, but the results will generally be better accepted if a group of people are involved.[21]

Element Method

The element estimate is more sophisticated than the analogy approach. It requires creation of individual estimates for each element or task in the project, which are added to form the overall estimate. Data created by this approach can be input to program evaluation and review technique (PERT) or critical path method (CPM) models.[22]

Top-Down Method

The top-down or CER approach is the dominant method today. It uses statistical analysis of data on the proposed project based on estimating relationships derived from historical records or a baseline database. Independent variables, including the factors contained in Table 1, are used to develop new CERs. CERs in use include:[23]

(1) Total object words.
(2) Total object words minus data areas.
(3) New object words minus data areas.
(4) Total lines of source code.
(5) New source code lines.
(6) Delivered code versus total code.

(7) Support software versus operational software.
(8) Units of work (modules).

A 1980 Hughes report documents the results of a survey in which decision makers were asked to rate each of the three methods with respect to criteria important for development of weapon system related software in the Air Force. Table 2 portrays the results of the survey.[24] The adjectives under the Bottom-up, Sideways, and Top-down headings can be used to compare the three methods with regard to the criteria in the leftmost column. Since the criteria influence development costs and time, selecting the estimating approach that best fits the project is important for budgeting and planning.

Cost Estimating Approach Performance Assessments
Weapon System Related Software

CRITERIA/DIMENSION	BOTTOM-UP	SIDEWAYS	TOP-DOWN
Data Requirements	Low	Medium	High
Design Evaluation Capability	Unlimited	Extensive	Some Limits
Verifiability	Difficult	Very Difficult	Very Difficult
Factors Included	Comprehensive	Limited	Limited
Applicability Range	Extensive	Extensive	Some Limits
Budgeting Accuracy	Medium-High	Medium	Medium-High
Input Data Required	High	Medium	Low
Maintenance Policy Eval Capability	Unlimited	Some Limits	Some Limits
Ability to Handle Uncertainty	Very High	High	Low
Algorithm Understandability	Easy	Very Easy	Some Difficulty
Analysis Required for Development	Limited-Extensive	Minimal	Limited-Extensive
Programming Reqd to Support Development	Limited-Extensive	Minimal	Minimal
Expandability	Extensive	Some Limit	Some Limits

(Hughes Aircraft Company, 1980)

Table 2.

The Hughes study concluded use of the bottom-up approach is the "most practical single cost estimating approach" for development of weapon system related software. (NOTE: This category was not included in the Doty study previously referenced.) This conclusion reflects the high risks involved in developing this type of software, the need to provide the program manager with enough flexibility to deal with that risk, and the "limited availability of historical data on which to build a model."[25] For business or scientific programs, the top-down approach is probably preferable in most situations, because it requires more detailed up-front analysis and provides more accurate sizing information.

Doty Manpower Model

$$MM = aI^{**}b$$

Where:
MM = man months
I = number of instructions
a = constant
b = constant

Figure 2.

Many organizations have developed internal estimators for various aspects of software development or support, but each has limitations. At present there does not appear to be a "general model" of software sizing that is any more accurate than the Doty Manpower Model (Figure 2).

As Doty Associates report:

> The cost estimates generated with these relationships have been subject to significant error. Much of this has been due to erroneous estimation of program size.[26]

The report goes on to say that the independent variables (including program size) only account for 30% of the variability.[27] If that is true, "traditional" problems involving, training, management, and communication probably deserve far more attention.

Conclusions

Two common threads run through the literature on software development: (1) task decomposition is widely accepted as the first step in a development effort and (2) present procedures are not satisfactory. This paper identified a number of variables and techniques which significantly affect software development and the accuracy with which software project costs and schedules can be estimated. Although many areas need improvement, the complexity of software and the people and organizations that develop it probably preclude dramatic advances. Many of the problems faced in software development are typical management problems. Determining objectives, allocating resources, setting standards, developing procedures, providing training, and communicating with workers are all critical in the software development environment.

Software sizing and estimation is a very complicated area of analysis. Although a number of studies have been completed, many of the critical processes and variables are still not well defined. High-level managers must recognize additional research is needed to understand the effects of current procedures and to formulate new methods.

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Aircraft Availability: A Concept Whose Time Has Come!

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Introduction

How much is enough? If the Air Force needs a certain number of F-15s, F-16s, or C-5s supported, how do we in the supply community make sure the parts for those platforms are there when needed? If we have only minimum financial resources, how can we spend them to best support the mix of aircraft needed by operations? These questions appear simple and straightforward; however, the answers are elusive and today the Air Force supply community really cannot tell how much is enough.

Despite that damning admission, there is some hope on the horizon. A concept called "aircraft availability" has been under test for some time. If its implementation is successful, we will, for the first time, be able to explicitly link supply purchase actions to operational capabilities. Implementation is currently scheduled to occur within the next year.

There is much technical information available on the concept. However, within this article, there will be no technical information (mathematical equations) presented to confuse or distract. That information is available in the references. The purpose of this article then is to provide a layman's overview of the process. To do so, I will begin with a brief background of the concept's development. The major portion of this paper will then focus on the "availability" concept. Finally, we will discuss the implementation of this concept within the Air Force.

Background

The Air Force has been actively looking for better ways to link supply support to some sort of operational standard. In fact, any examination into supply systems has included a call for more explicit linkage between supply and operations. The latest such call came from the DOD Supply Management Policy Group, representing the Services and the Defense Logistics Agency (DLA). Their published report calls on all Services and DLA to provide supply support based on operational or weapon system availability—a system which ultimately will produce attractive benefits:

> Reorientation of stockage policy from an item approach to a weapon system approach will provide better weapon system readiness from available materiel funding by developing stock levels at each supply echelon tailored to each item's impact on weapon system readiness. Enhanced assessment capabilities will improve justification of budget submissions and will provide weapon system operators information on the level of weapon system support that can be expected from available or projected spares and repair parts.

What does all this mean? Up to this point, some intelligent and dedicated people have recommended an improved method of providing supply support. However, no technique or model was around to give us that capability—until fairly recently. Since the early 1970s, the Logistics Management Institute (LMI) has been experimenting with methods to link spares buys to operational capabilities. The end product of these efforts was development of the aircraft availability model (AAM).

With the completion of the model, LMI published formal documentation on the conceptual framework and mathematics in 1983. At that point, the Air Force supply community investigated the usefulness and applicability of this tool to current supply systems. The major conclusion of the study was that this model would substantially improve the quality of supply support. Based on that conclusion, the Air Force Logistics Command (AFLC) began to incorporate the model into the Air Force requirements computation system.

Aircraft Availability Overview

The aircraft availability model changes forever the way that supply support is provided and measured. Rather than focusing on fill rates, AAM acquires parts and measures performance against the ability of the supply system to provide operational aircraft. To understand this concept thoroughly, the discussion will concentrate upon three areas:

(1) The "big picture," which will provide an overview of the concept including key definitions.

(2) An operational example, to further refine the concept.

(3) The operation that makes the whole system work—the goal-setting process.

The Big Picture

Any discussion of aircraft availability must begin with the question: What is an available aircraft? Within supply, we are only concerned with one major thing—spare parts. As a result, aircraft availability, as defined by the supply community, is considered within a fairly narrow context. An available aircraft is one that is not awaiting a resupply action. The parts are there. The maintenance action may not have been completed. The crew may not be available. But, to the supply community (and to our availability model), the aircraft is available.

Aircraft availability represents a "wholistic" view of spares needs. It is a method to get the right mix of spares to generate aircraft. To perform this very important function, the aircraft availability model computes cost curves for budget purposes and buy lists for purchases of spare parts. The cost curves are the result of internal calculations by the model as to how many aircraft will be available for a given investment in spares. With this information, we can build a budget against the operational community's needs. Buy lists are generated after the operators have identified their needs, and the lists represent specific order quantities (by stock number) needed to attain the desired

level of aircraft availability. All of this magic is performed using a complex series of mathematical formulas. For more information on the specifics, consult the references.

The key difference between the availability model and the current system is one of philosophy. Each system is effective if there is ample money available. However, as funding becomes even more critical, we cannot afford the luxury of unlimited stocks in the hopes of avoiding stockouts or backorders. We must have some criteria to place emphasis where needed and to keep the system economical. Under the current system, we try to put parts on the shelf that are ordered often. AAM attempts to provide a balanced mix of spare parts so that fully spared aircraft can be generated. The current system maximizes fill rates. AAM maximizes aircraft not awaiting spare parts.

Aircraft Availability Example

A simple example will illustrate the internal workings of the model as well as show differences with the current system. Let us assume, for the moment, that we have an aircraft that uses an onboard computer. The key elements of that computer—the only ones that we will be concerned with—are a circuit card and a computer screen (Figure 1). With this relationship established, the way that aircraft availability and the current system use this structure can be described and contrasted.

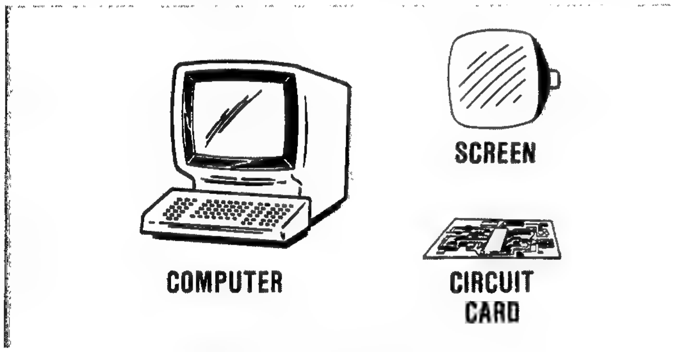

Figure 1: Onboard Computer Example.

The central issue for supply support is, What is the mix of computers, cards, and screens that should be purchased to support operational needs? The way that we view the linkage among these parts is important (Figure 2). The current system views each part as essential. In other words each part receives equal treatment. The aircraft availability concept views relationships more as they exist in the real world. Computers return aircraft to ready condition. Cards and screens return computers to good condition. This basic difference in perspective dictates different purchase philosophies.

Remember, this concept is designed to use the best mix of spare parts to support operational needs. For purposes of discussion, we will focus on two possible inventory positions. We will either have sufficient computers to meet our needs, or we will not have sufficient computers to meet our needs. The solutions between the way we do things today and the aircraft availability model will vary substantially.

Assume there are sufficient computers to meet all anticipated future needs. Neither the current system nor the aircraft availability model would purchase additional computers. The present system, however, would purchase circuit cards and screens in keeping with its view of the world. That is, computers, cards, and screens are all equally important to the aircraft. Conversely, the availability model

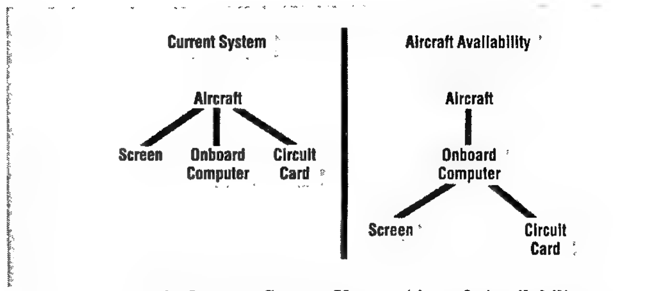

Figure 2: Current System Versus Aircraft Availability.

would buy no additional circuit cards or screens. Remember, cards and screens return computers to good condition. Since there are sufficient computers, there is no need to purchase additional cards or screens. Under this condition, AAM would actually be less expensive than the present system since we would not be pushed to purchase additional unneeded parts.

What if there are not sufficient computers to meet operational demands. Both systems would purchase computers, cards, and screens. The current system would buy a mix of all parts with each being viewed as contributing equally to support. Therefore, each part would compete equally for money. We could easily end up with abundant cards but not enough screens to repair needed computers. AAM would attempt to balance the needs. The mix of cards and screens would be balanced to generate the needed number of computers. Any resulting shortfall would be covered by the purchase of additional computers.

Goal-Setting Process

Given that the aircraft availability model works as advertised, what makes it go? When we have more than one aircraft and a variety of parts, what happens when there is not enough money to go around? Some systems may be more important or demand more attention than others. How do we recognize that? One of the interesting features of the AAM is that support objectives or goals can be assigned to recognize different support needs.

The aircraft availability model, for each weapon system, builds a table that relates goals or support objectives to cost. The model accumulates this information as it goes through the calculations described in the previous example. Essentially, each table (Figure 3) displays a percentage figure and a cost.

Weapon System: F-XX

Percentage	Cost (In Millions)	Percentage	Cost (In Millions)
100	200.7	75	178.7
95	190.4	70	174.6
90	185.7	65	173.0
85	183.2	60	171.3
80	180.0		

Figure 3: Availability Cost Graphic.

The percentage represents the support objective or that percent of the fleet that will be supported as "available aircraft." The cost opposite the percentage is the amount of money that must be invested to achieve that particular support objective. The table can be portrayed graphically (Figure 4) to provide a better view of the information. As shown, a curve of availability can be computed for each aircraft type. A different

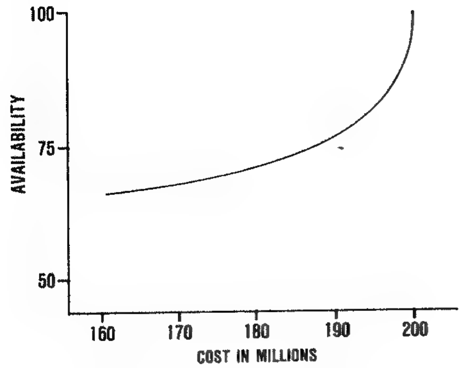

Figure 4: Availability Cost Curves.

support objective or goal can be selected on each weapon system curve.

The support objectives selected for each weapon system can be used to determine a budget submission or to decide what mix of spares to purchase. To build a budget, merely sum up the selected support objectives across all weapon systems. To allocate monies, different points on each system cost curve can be selected to provide the mix of aircraft necessary to meet operational needs.

The support objective or aircraft availability goal must be meaningful. On one hand, it ought to provide a means to allocate funds equally or unequally across weapon systems. On the other, the support objective should equate to that number of fully supported aircraft which is needed to support the operational mission. The operational community is still grappling with a methodology to indicate the support objective. The aircraft availability model is dynamic enough to support any number of support objectives (Figure 5). The objectives may be very macro in nature—across large groupings of systems—down to the very specific, and all points in between.

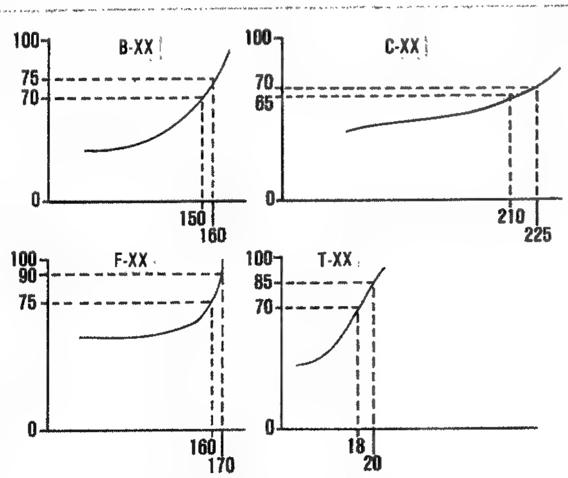

Figure 5: Various Cost Curves.

Air Force Implementation

We have established how the aircraft availability model came to be and how it basically functions. Given the capabilities of AAM, how does the Air Force intend to use this concept? The aircraft availability model represents our first effort at directly relating spares to some operational measure. As such, the initial Air Force implementation will be limited. Current plans call for its "for real" implementation in the near future. The scope of the implementation will be discussed within the remainder of this section.

The initial implementation of this model will be limited to recoverable or repair cycle items. In fact, not all recoverables will be subject to this concept. Only those Air Force centrally-managed recoverables that can be directly linked to an aircraft will be included in this process. All other recoverables, equipment items, and consumables will be managed the same as they are today.

The implementation will be further limited by focusing exclusively on the PURCHASE of recoverables. As a result, aircraft availability will be used only within the AFLC recoverable requirements computation system. Base level systems will remain unchanged. Again, only the AFLC system will change. And, even within that system, the change will be limited to how safety levels are computed. Essentially, all pipelines (repair, resupply, etc.) will be purchased as today. However, the method of allocating safety levels worldwide will change under this system.

Because of this limited approach, the goal-setting process takes on limited meaning. We are only setting goals on a very narrow range of items and only for purchase. As a result, there will not be a lot of precision in the support objectives. It may not make sense, for example, to agonize over whether to set support objectives at 86% versus 87%. We may not, in real terms, be able to see much difference. What we are trying to do is to lay in a pool of spares for a particular fleet of aircraft. The objective is to support a level of effort by providing a viable base of spares. There are just too many other variables to expect much more.

Conclusion

The aircraft availability model is a significant advance in supply support. For the first time, the supply community will be able to link supply support to operational capabilities. Internally, AAM provides a means to buy parts smarter, giving a better mix of parts needed to generate aircraft. Externally, AAM enables us to work with the operational community to provide a level of spares support commensurate with operational needs.

More importantly, the successful implementation of aircraft availability sets the stage for the expansion of this concept into other logistics-related fields. Repair and distribution networks that respond to aircraft availability goals, for example, could be developed. Conceptually, the entire logistics network could be tied directly to operational objectives. Changes in operational needs could be reflected immediately in timely logistics support. We start with supply. We finish with logistics. The objective is available—ready to fly—aircraft.

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AFIT School of Systems and Logistics Completed Theses and Follow-on Research Opportunities

The Air Force Institute of Technology's thesis research program is an integral part of the graduate education program within the School of Systems and Logistics. The graduate thesis research program is designed to contribute to the educational mission of AFIT's Graduate Program through attainment of the following specific objectives:

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(2) Enhance the student's knowledge in a specialized area and increase the student's understanding of the general logistics environment.

(3) Increase the professional capabilities and stature of faculty members in their fields of study.

(4) Identify military management problems and contribute to the body of knowledge in the field of military management.

Organizations that have potential research topics in the areas of logistics management, systems management, engineering management, and contracting/manufacturing management may submit the topics direct to the School of Systems and Logistics, Air Force Institute of Technology (Lt Col Gary L. Delaney, AUTOVON 785-4845).

The graduate theses listed in this article were completed by Class 1986S of the Air Force Institute of Technology's School of Systems and Logistics. AFIT Class 1986S theses are presently on file with the Defense Logistics Studies Information Exchange (DLSIE) and the Defense Technical Information Center (DTIC).

Organizations interested in obtaining a copy of a thesis should make the request direct to either DLSIE or DTIC, not to AFIT. The "AD" number included with each graduate thesis is the control number that should be used when requesting a copy of a thesis from DTIC. The "LD" number should be used when ordering from DLSIE.

The complete mailing addresses for ordering AFIT graduate theses from DLSIE and DTIC are as follows.

DLSIE	DTIC
U.S. Army LMC	Cameron Station
Ft Lee VA 23801	Alexandria VA 22314
(AUTOVON 687-4546/3570)	(AUTOVON 284-7633)

CLASS OF 1986 THESES

Capt Steven J. Barlow *Prototype of a Computer Method for Designing and Analyzing Heating, Ventilating and Air Conditioning Proportional, Electronic Control Systems*	ADA-174617 LD69961A
Capt Stephen A. Bird *Economic Feasibility of Fuel Cell Energy Systems for Selected Facilities on Wright-Patterson Air Force Base, Ohio*	ADA-175124 LD69968A
Capt Scott K. Borges *An Evaluation and Proposal of United States Air Force Uses of Roller Compacted Concrete Pavement*	ADA-175041 LD69964A
Capt John K. Borland *An Investigation of Personal Background Factors Related to the Civil Engineering Officers' Satisfaction with the Air Force Way of Life*	ADA-174423 LD69828A
Capt Harry Briesmaster III *An Examination of the Air Force's Bare-Base Design in Terms of the Impact on Air Base Survivability Using Computer Modeling Evaluation*	ADB-107649 LD69739A
1Lt Kevin R. Clover *A Survey of Knowledge about and the Attitudes toward Maneuver Warfare Tactics in the Second Marine Division*	ADB-107055 LD69489AX
Mr Steven W. Coyle *Measurement of Air Force Environmental Protection Program Performance*	ADA-174296 LD69819A
1Lt Steven W. Ditmer *An Analysis of the Relationships Between Air Force Civil Engineering Organizations and the Air Force Suggestion Program*	ADA-174587 LD70075A
Mr George M. Drewett *Hazardous Waste Management: A Descriptive Study*	ADA-174346 LD69131A
Capt Gerald B. Dutcher *An Investigation Concerning Perceptions of Military Construction Program Effectiveness by the AFRCES, the MAJCOMs and the Bases*	ADA-174466 LD69134A
1Lt Robert J. Grimm *Attribution of Base Civil Engineering (BCE) Leadership by Key Subordinates*	ADA-175037 LD69766A
Mr Eldon E. Hix *An Analysis of Factors Related to Retirement Intentions of Upper Level Civil Service Employees in the Air Force*	ADA-174343 LD69238A
Capt Richard J. Ingenloff *An Assessment of Air Force Civil Engineering Officer Perceptions of Assignments to Career Broadening Positions*	ADA-174496 LD69988A
Capt Donald J. Kellogg *Information Requirements for the New Contract Programmer*	ADA-174564 LD70078A
Capt Dale R. Lavigne *Investigation of Air Force Built-Up Roofing Tolerances*	ADA-174539 LD69794A
Capt Danny S. Long *Customer Management Skills for Effective Air Force Civil Engineering Customer Service*	ADA-174114 LD70103A
Capt Douglas C. Miller *Engineering and Scientific Career Continuation Pay (ESCCP) and the Retention of Air Force Engineering Officers*	ADA-174626 LD69966A
1Lt James P. Mitnik *Computer-Aided System Needs for the Technical Design Section of the Base Level Civil Engineering Squadron*	ADA-175038 LD69990A
1Lt Spencer H. Patterson *Harvest Eagle Management: A Case Study*	ADB-107298 LD69772AX

Capt Roderick D. Reay ADA-174593 LD70077A
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Capt Sean O. Saltzman ADB-107099 LD69283A
An Investigation of Site-Specific Information Requirements for Deployable Prime BEEF Teams

Capt Kenneth R. Singel ADA-174116 LD70101A
Measurement of Civil Engineering Customer Satisfaction in Tactical Air Command A Prototype Evaluation Program

Capt Keith E. Smith ADA-174565 LD69994A
Cost Comparison of Technical Training School Versus Unit Training Methods for Direct-Duty Airmen in Civil Engineering Air Force Specialty Codes

Capt Paul W. Somers ADA-175089 LD69769A
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Capt Steven R. Stark ADA-175001 LD69209A
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(The conclusion of this listing will appear in the Summer issue.)

▶ *Continued from page 35*

[15] Brooks, 1975, p. 78.
[16] Doty Associates, Inc., Jun 1977, p. 1.
[17] Boehm, pp. 47-55.
[18] Doty Associates, Inc., Aug 1977, pp. 2-10.
[19] Hughes, p. 84.
[20] Doty Associates, Inc., Jun 1977, p. 17.
[21] Hughes, p. 84.
[22] Hughes, p. 85.
[23] Doty Associates, Inc., Jun 1977, p. 65.
[24] Hughes, p. 90.
[25] Hughes, pp. 94-95.
[26] Doty Associates, Inc., Jun 1977, p. 120.
[27] Doty Associates, Inc., Jun 1977, pp. 120-122.

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General Charles L. Donnelly, Jr., USAF, Retired, believes people are our most important Defense System--

"What does the future hold? No one knows, but I do know that the F-15 sitting cocked and ready to defend freedom is a useless piece of equipment without the human to maintain it and fly it. This applied equally to ships, tanks, and all other military equipment."

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